FOUNDATIONS™ For Conveyor Safety

The Global Best Practices Resource for Safer Bulk Material Handling

First Edition

FOUNDATIONS™ For Conveyor Safety

The Global Best Practices Resource for Safer Bulk Material Handling

FOUNDATIONS™ For Conveyor Safety

The Global Best Practices Resource for Safer Bulk Material Handling

by

R. Todd Swinderman, P.E.

Andrew D. Marti

Daniel Marshall

Martin Engineering Company
Neponset, Illinois
U.S.A.

This book is published as a service to the global bulk-materials-handling industries and their workers. It is not a substitute for professional engineering advice or judgment, and its content should be carefully evaluated by professionals to determine suitability for any specific project. In particular, any user should research and consider, in addition to the standards quoted and described herein, their full context, and other relevant legal and professional standards, requirements, and recommendations. No warranties are made as to the contents of the book or its application to any situation. Your sole remedy for any complaint about the book or its contents shall be a refund or replacement.

If you find any errors, or if you wish to provide additional information, clarification, or other input for future editions, please contact Martin Engineering, (Safety Book Team) at info@martin-eng.com, by phone: 309-852-2384, or 800-544-2384, or by fax 800-814-1553

Application of the information and principles in this book should be carefully evaluated to determine their suitability for a specific project.

For assistance in the application of the information and principles presented here on specific conveyors, consult Martin Engineering or other knowledgeable safety personnel.

FOUNDATIONS™ For Conveyor Safety

ISBN 978-0-9717121-1-3-3

Library of Congress Control Number: 2016901217

Part Number L4049-9/16

Printed in the United States of America.

Printer: Worzalla Publishing Company,
Stevens Point, Wisconsin

Martin Engineering Company
One Martin Place
Neponset, IL 61345-9766 USA
800-544-2947 or 309-852-2384
Fax 800-814-1553
info@martin-eng.com
www.martin-eng.com

Preface

The link between safety and productivity

Edwin H. Peterson
Chairman and CEO
Martin Engineering

Robert J. Nogaj
President and COO
Martin Engineering

We think this book is the first of its kind. It represents a global roundup of the best practices for safer design, operation, and maintenance of belt conveyors for bulk materials.

Our work is based on the premise that the extraction and processing of bulk materials can be done safely and profitably by seeking out and applying global best practices for conveyor safety and design.

The first step to true productivity is safety. If a machine, a plant, an industry is safe, it can be productive; if it is not safe the plant, the process, the conveyor cannot be truly productive. And that means the operation cannot be successful financially. The key is **Production Done Safely™**.

With the rising volumes and diversity of material carried, the ever-increasing size and speed of equipment, and the continuing pressure to improve efficiency, bulk-materials handling can be dangerous. However, when managers discuss improvements, they focus on production. That is their goal; that is their charge; and that is why the company is in business.

From the beginning, Martin Engineering has been committed to increasing productivity and safety in bulk-materials handling. Working in his basement workshop in 1944, our company's founder, Edwin F. Peterson, came up with an answer to one of the problems in bulk-materials handling, the ball-type industrial vibrator. His inventiion, marketed as the VIBROLATOR®, provided the foundation for the success of Martin Engineering. Since that time, Martin has expanded with operations or licensees around the globe, used wherever bulk materials are handled. Many of our later products and services have focused on improving plant cleanliness, controlling fugitive material to improve performance, and reduce hazards within the operation.

And now we direct our attention to improving safety, as we know there is not productivity without safety.

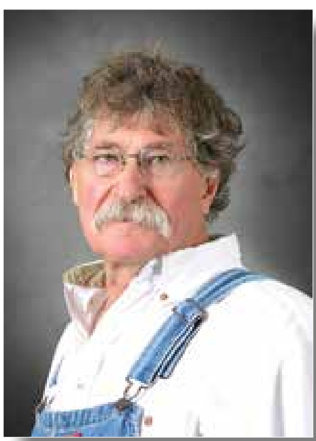
We feel we need to help change a mindset; we want to be counted among those who are setting a higher standard; and we need to be a part of changing the culture of our industry.

With this book, Martin Engineering takes the first step.

Dedication

It is an honor for the Peterson Family to dedicate the first edition of *FOUNDATIONS™ For Conveyor Safety, The Global Best Practices Resource for Safer Bulk Material Handling* to the following:

R. Todd Swinderman, P.E.: Graduating from the University of Illinois in 1971 with a Bachelor of Science Degree in Mechanical Engineering, Todd is one of the principal driving forces behind this publication. Internationally known for his innovative engineering contributions to the bulk-materials-handling industry, he has also been instrumental in developing consistent standards for the industry through the Conveyor Equipment Manufacturers Association (CEMA). Todd served as the association's president as well as committee chair for both the sixth and seventh editions of CEMA's *Belt Conveyors for Bulk Materials*. Possessing seven Professional Engineering (P.E.) licenses at one time in his career, and as a former President and CEO of Martin Engineering, Todd's guidance, influence, and professional engineering experience have touched every facet of conveyor operations throughout the world. He holds over 60 United States patents and numerous corresponding foreign patents. After spending more than 30 years in the industry, he now shares his expertise as an independent consultant.



Richard P. Stahura, Sr.: A safety advocate for over six decades for the bulk-materials-handling industry, Dick, Sr. has been many times the lone promotional voice for conveyor safety. Along with Todd, he also has been an influential force for *FOUNDATIONS™ For Conveyor Safety, The Global Best Practices Resource for Safer Bulk Material Handling*. He preaches that environmental and safety rules and regulations must be incorporated into conveyor design priorities. In fact, instead of waiting until governmental regulators threaten fines or force a shutdown of operations, environmental, safety, and health issues will ultimately take the place of production as the number one priority for design engineers as well as conveyor owners. With a reputation as a colorful character, he has become known worldwide for his signature denim bib overalls.

Daniel Marshall: Dan received his Bachelor of Science degree in Mechanical Engineering from Northern Arizona University. Working for more than 16 years for Martin Engineering, Dan has been instrumental in the development and promotion of multiple belt conveyor products. He is widely known for his work in dust suppression and considered a leading expert in this area. A prolific writer, Dan has published over two dozen articles covering various topics for the belt conveyor industry; he has presented at more than fifteen conferences and is sought after for his expertise and advice. Because Martin promotes community involvement, he volunteered to become one of the founding advisors to the Martin high school robotics team. Serving as one of the principal authors of Martin's *FOUNDATIONS™ The Practical Resource for Cleaner, Safer, and More Productive Dust & Material Control, Fourth Edition*, his dedication to the conveyor industry and Martin Engineering is unparalleled. Dan is truly one of the 'giants' in the Martin Engineering Family.

Notes from the Authors

Martin Engineering offers this book as a service to bulk-materials-handling industries—and their workers—around the world.

This volume is provided for general information purposes only and is not intended to provide comprehensive or specific knowledge pertaining to the regulations, standards, and recommendations associated in bulk-materials-handling operations. Excluding these regulations and standards and directly quoted material, the opinions expressed herein are those of the authors and represent a consensus of the authors regarding the topics covered.

Application of the information and principles in this book should be carefully evaluated by knowledgeable authorities to determine suitability for any specific conveyor or project.

We now offer a few notes explaining the philosophy and conventions adopted for this volume.

Audience Assumptions

This book is written for those who design, operate, and maintain belt conveyors—so each knows what can and should be done to protect workers around these conveyors. The audience also includes the 'safety manager' who does not know much about belt conveyors, and the 'belt boss' who only knows a little about safety regulations and requirements. Finally, the book is written for the supervisor or plant manager with responsibilities for both a plant's operations and its safety, but with precious little time or few resources for either. The book will help management personnel guide the workforce in working around belt conveyors. It will also help managers and engineers justify the expenditures—for initial design and retrofit upgrades—that improve conveyor safety.

Standards and Dates

Most standards are published with a date appended to the standard's number, indicating the year the version was released. Where possible, these dates are included as a guide to the specific version of the standard under discussion.

In their descriptions of a standard, some issuing bodies include a notation of previous editions or standards that have been superseded.

Keeping abreast of changes in regulations, standards, and guidelines is a continuous process. During the writing of this publication, the Australian standards were updated from *AS 1755-2000* to *AS/NZS 4024.3610-2015* and *4024.3611-2015*. *EN 953* was superseded by *EN ISO 14120* on May 31, 2016. Within one month of our press date, the guideline *Safety Around Belt Conveyors* from the Conveyor Manufacturers Association of South Africa was updated with a 2016 version. All these updates required changes to chapters we had thought 'done.' While we have worked to keep up with these changes—to the distress of those charged with laying out pages to send the printer—there may be updates we missed. Regardless, there will certainly be occasions in future where the text here will be superseded by changes in technology, in requirements, or in best practices. Our advice is to stay on top of the changing environment and to select competent engineers and suppliers who do likewise.

In all cases, the current version of applicable standards and regulations should be obtained and consulted to verify its requirements.

Translated Standards

In some cases, the text of a standards printed here may seem awkward or badly written; this is particularly true of standards which originate in languages other than English. Rather than 'correct' these translated passages to the authors' taste, these translated standards are published as we found them available. As always, it is a wise course to consult the source document in its original language.

Measurements

In this volume, dimensions and other measurements are presented in both Imperial and metric units. A measurement will be shown first in the system in which it was originally presented. Following that, a conversion to the other system will be presented; in most cases this conversion to the other system will be shown in brackets [ ]. These brackets indicate the conversion was made by Martin Engineering.

If the second measurement is shown in parenthesis— ( ) —this indicates the source material itself included the converted measurement.

A double tilde (≈)—the mathematical symbol for "approximately equal to"—will be placed before the second measurement; this indicates that number is a conversion from the original unit and (where appropriate) has been rounded.

All rounding will be in the direction of greater safety; in some cases, this will not be the nearest measurement.

In most cases, a period has been used as the decimal marker in metric measurements. This is the style in North America where the authors are located and with which they are most familiar.

Illustrations

Pictures, graphics, tables, and charts contained in this book are used to convey specific points and, therefore, may not be technically correct or complete in every detail.

Names and Data

Fictitious names and data provided in this book are intended to convey concepts and any similarity thereof to actual entity names or data is purely coincidental and unintentional.

Information on incidents presented here represents the authors' best understanding of causes and outcomes, with no intent to blame, defame, or disparage.

A Note on Sources

Rather than use extensive footnoting in this volume, we have tried to introduce the sources in the chapter text. There is a more detailed listing for these sources, organized by chapter, in the bibliography.

A Caution

This book is provided without representations or warranties as to the accuracy or completeness of the content of the book. The BEST PRACTICES sections of this book are intended to highlight specific safety issues and should not be considered as inclusive of all best practices related to all bulk-materials-handling operations and all circumstances.

Foreword

By R. Todd Swinderman, P.E.

I have spent decades trying to design, install, and maintain belt conveyor components that control fugitive materials, and so improve the working environment, reduce accidents, and increase productivity. But now, we have reached the point of diminishing returns. To achieve the next level of improvement in reducing conveyor accidents, we need to change the way we specify, design, purchase, operate, and maintain conveyors.

It has been estimated that 85 percent of bulk belt conveyor maintenance and production problems are related to fugitive materials—dust, spillage, and carryback. It is my belief that a similar percentage of conveyor safety issues arises from these same fugitive materials. However, once the conveyor is designed, built, installed, and operational, solving fugitive material problems becomes virtually impossible.

This leads to the question: Why do we design conveyors the same way we have for more than one hundred years? Often, there are no reasons, just excuses: 'We have always done it that way,' or worse, 'We have to be competitive.' As demonstrated by the relatively constant fatality rates associated with conveyors over the last thirty to forty years, these attitudes and these techniques simply no longer improve safety, despite numerous new regulations, increased civil penalties, and universal adaptation of safety slogans.

The Start of the Safety Industry

Herbert W. Heinrich's 1931 book, *Industrial Accident Prevention, A Scientific Approach*, was based on summarizing thousands of accident reports. Heinrich concluded it was the worker's unsafe acts that were the primary cause of accidents. Unfortunately, this thinking continues to dominate the opinion of most managers and supervisors. Yet most safety professionals have realized for some time that the root cause(s) for accidents are not that simplistic.

In most cases, writing in an accident report that the incident's root cause was an unsafe act is a simplistic excuse for a less-than-thorough investigation. Often, the act is not the only, or even the most, significant root cause. To believe—in perfect hindsight—that the root cause was a single unsafe act is to assume the worker's actions were done with perfect foresight. The real root causes are more involved and require a more complete accident analysis and followed by thoughtful corrective action.

I have come to the conclusion that there are five root causes that lead directly to an increased release of fugitive materials and result in scenarios that encourage workers to react the way they do. These five root causes are: a 'Production First' Culture, 'Low Bid' Purchasing, Overly Complex Designs, Too Many Rules, and Understaffed and Undertrained Maintenance.

Root Cause:
A 'Production First' Culture

Corporate websites and mission statements are full of language that obscures or hides the real corporate culture. Without fail, when entering a plant a huge billboard proclaims the company is 'world class' in safety. This sign features current buzz words like ISO, sustainability, green, global warming, and so on. Although when you walk past the billboard reality sinks in, and usually world class can quickly be seen as worst in class.

When the focus is on production at the cost of all else, it is no wonder workers take risks to keep the conveyors running. Safety slogans and environmental messages become a smoke screen to what is really going on. The workers see the same thing—that production comes before safety.

Obviously, the reason a company operates mines and processing plants is production. So to counter the hypocrisy, corporations would be better off admitting that production is the focus. I maintain the goal should be **Production Done Safely™.**

Root Cause:
'Low Bid' Purchasing

Poor management culture starts in the Board Room, where decisions on capital expenditures are based on feasibility studies that only consider direct revenues as seen in conventional accounting practices. The 'value added' from safety and health enhancements is never considered during the feasibility stage or anywhere else in the procurement process.

Historically, purchasing decisions are almost universally based on a 'low bid' process. But in meeting artificial capital constraints, key equipment specifications are compromised and design details are deferred but are never adequately budgeted. The details are left to be resolved as operating costs (and often maintenance expense) and so are never adequately considered in the engineering or construction phase.

Not enough attention is paid in the specification and design process for risk mitigation. The low bid process prevents design firms from including the costs of sending engineers to the field to see the results of their designs and gain the experience necessary for continuous design and safety improvements.

The cost of 'buying cheap' can get very expensive. A low bid system often fails to deliver the required production capacity. Instead, the focus should be on lowest cost over the life of the project. Low bid designs often turn out to be the most expensive, because they can result in significant costs for late modifications as a result of issues discovered during trials and start-up.

The result, in my opinion, is this: The 'low bid' process kills people.

Root Cause: Overly Complex Designs

Complexity does not necessarily improve safety. Simple designs are often harder to realize; the extra design time required to simplify the operation of and the maintenance on conveyor components that directly affect production and cleanliness has an enormous payoff. Unfortunately, the same benefits are almost impossible to incorporate in low bid designs due to the intersection of the customer perception that those 'cost too much' and the supplier's need to 'win the bid.'

Root Cause: Too Many Rules

When I recently visited a quarry, the visitor safety orientation was 14 pages long, and I was only providing training, not operating or working on any equipment.

In my advanced seminars I often ask, "Who can stand up and repeat their company safety rules?" I have never had one person be able to recite their company's rules. What are the chances that the worker will remember the appropriate rule(s) from a myriad of rules in the heat of a conveyor breakdown? I would estimate the chances are pretty close to zero.

However, another company had a commonsense approach; their basic safety rules consist of 12 general rules. The chances of a worker remembering, practicing, and supporting their co-workers by testing their actions against a dozen general safety guidelines are pretty good.

Industry groups and associations, standards-writing organizations, and countries have issued thousands of pages of safety rules. In many cases, rules within a country contradict each other or are not applicable to the industry in which they are enforced. The effort required for suppliers to comply with the myriad of rules is immense; these efforts are often negated by the varying opinions of a multitude of inspectors. The probability of conforming to the complexity of all regulations and passing inspections is problematic at best.

Root Cause: Understaffed and Undertrained Maintenance

The lack of adequate funding for maintenance is epidemic in the bulk-materials-handling industry. Millions are spent on components, yet this expense is without the added maintenance budget needed to keep the components in a sound and safe operating condition. Generally, the size of a maintenance crew is based on Mean Time Between Failure (MTBF) for major pieces of equipment with the illogical conclusion that workers can maintain all the minor components in the system in their 'spare' time.

Most equipment is not designed for easy inspection or safe maintenance. So, during the scheduled production outages—which are becoming shorter and less frequent in the false belief that running 'flat out' increases production—maintenance of minor components must often be deferred due to access conflict, lack of time, or budgetary constraints. This further reduces the component's functionality, often to the point that it becomes useless and unrepairable.

Since the conveyors are designed to be sturdy, the belt can be dragged across piles of dirt or inoperative idlers, as long as the major components are kept running. If the components critical to maintaining a clean and safe work environment were made service-friendly and provided with adequate access, much of the beneficial maintenance can be done *safely* while the conveyor is in operation.

While most maintenance workers are skilled technicians, they rarely understand the conveyor as a system. Conveyors are complex systems; a change to one component will often have unintended consequences for the system. Without a basic understanding of how conveyors are designed and components selected, maintenance becomes an exercise in finding the longest-lasting 'band aid' to treat the symptom(s) rather than solving the root cause(s). Before long, an accumulation of bad choices in treating symptoms results in a system that cannot operate optimally. Treating symptoms shortens component life—it is often belt life that is sacrificed—resulting in the need for increased spare parts which in turn increases the need for maintenance labor. The evidence of this foolish approach is easy to find—walk the plant and look for the red tags on inoperative equipment. Chances are the tags are dated months—if not years—prior. As a result, the equipment sits, begging for the maintenance attention that never comes.

Safety Pays

Chances are that including safety in a financial analyses to justify additional design time, and purchasing on the basis of lifecycle costs rather than low bid will have a much bigger return than one can imagine. A survey of the literature shows that companies who truly focus on safety are more productive, operate cleaner and safer facilities than their competitors, and have a higher share price.

Checking the Books

The series of *FOUNDATIONS™* books from Martin Engineering has focused on providing operations and maintenance personnel with practical solutions to the common problems associated with bulk-materials-handling systems. The recommendations and methods detailed in *FOUNDATIONS™ Fourth Edition, the Practical Resource for Cleaner, Safer, More Productive Dust & Material Control* have become industry-standard approaches to solving these problems.

However, this volume represents a change in direction from our former tradition and focuses on bulk-materials-conveyor safety. The intent for *FOUNDATIONS™ For Conveyor Safety, The Global Best Practices Resource for Safer Bulk Material Handling* is to be used in conjunction with *FOUNDATIONS,™ 4th Edition.*

At the End of the Day

Throughout this volume, our theme is that conveyors can and should be made safer, and that there are sound economic reasons to do so. We put this book together in hopes you can learn, and then achieve, the benefits of **Production Done Safely™**. ⚠

R. Todd Swinderman

Introduction

THE NEED TO IMPROVE CONVEYOR SAFETY

Chapter 1

The Mission

Production Done Safely™

INTRODUCTION

In this volume, we will be looking at ways to improve belt-conveyor safety. But first, we need to look at both conveyors and safety as general topics, to see what their purposes and goals are, what these systems share, and how they can be aligned more closely.

A Positive View of Safety

Safety is at a turning point. The focus on gathering and analyzing negative data (incident reporting) has produced little return on the investment—and little reduction in accident rates—over the last several decades. This is evidenced by a stubborn resistance to a reduction of work-related fatality rates. **Figure 1..** shows a dramatic drop in United States mining industry accidental death rates in the early parts of the 20th century until the mid-1970s; after that, the accident rate has stabilized or plateaued. As the figure indicates, even with increasing amounts of regulation and corresponding enforcement, there has not been a statistically significant reduction in the accidental death rate in the last 40 or 50 years.

It is not just in mining and other bulk-materials-handling operations where this 'leveling off' trend is evident; it can be found in every major industry. This plateau in fatalities shows that the ongoing increase in regulation is not improving safety. This trend indicates the 'safety systems' are becoming more bureaucratic and subjective without a corresponding improvement in safety. Similar charts can be drawn for other countries.

It has become obvious that this methodology of increased requirements and regulations has reached the point of diminishing returns. What has been done to improve safety is important and should be continued, but it is not providing the benefit of significantly improved safety for workers.

In addition, the focus on 'negative' data—that is, the number and type of incidents—as a predictor of the probability and the severity of future accidents is problematic. There are many factors of this data that cloud the picture.

The tendency to blame unsafe acts of the worker for accidents and injuries is among the key reasons the focus on negative data is ineffective. This masks the underlying root causes and, therefore, prevents meaningful corrective action. Ignoring the root causes and only treating the symptoms fuels an increase in less effective, but easily implemented, rules and regulations. It is easier to make a rule that solves a symptom than it is to change a culture to solve a problem. Another factor is the perceived low probability of an accident, which feeds a common human justification that 'it won't happen to me.' In addition, there are significant differences in how countries report—or do not report—accident data, making worldwide comparisons difficult without the liberal use of estimates.

With few negative data points to use to predict future problems and the corruption of the data by incorrect cause analysis, these methods of accident prevention are unlikely to result in any meaningful reduction in industrial accidents.

There are many individual studies showing that a focus on safety improves production and profit. But we have yet to 'connect the dots' represented by these studies in order to move the topic of conveyor safety from one of individual experiences and experiments into

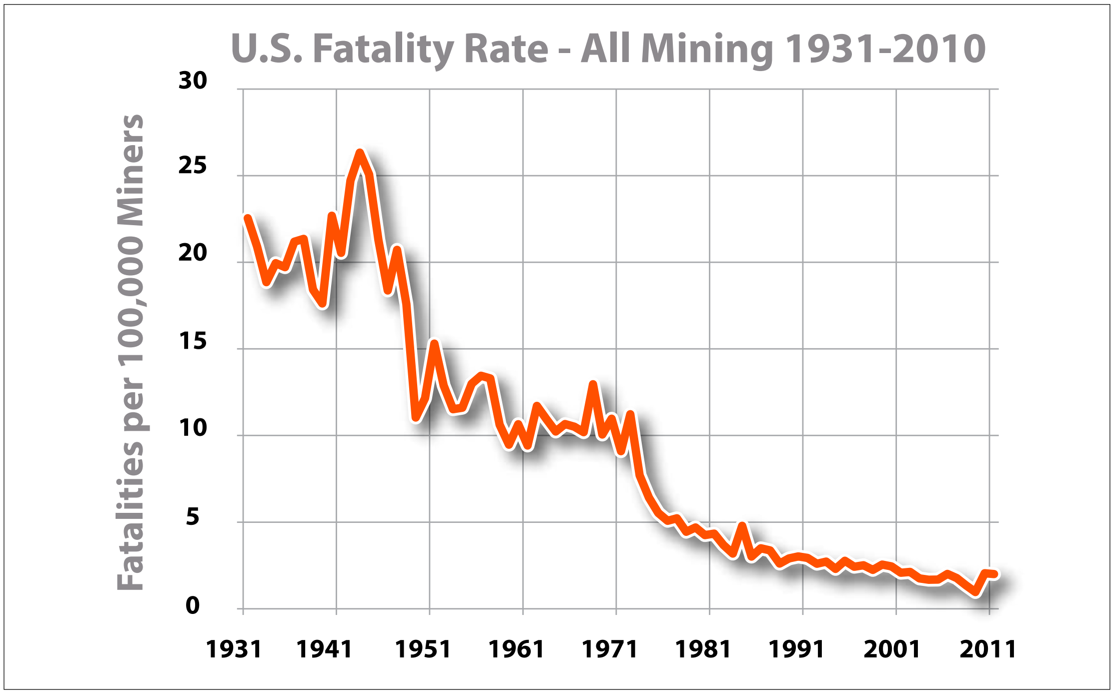


Figure 1.1.

After declining dramatically until the mid-1970s, mining fatality rates in the United States have leveled off. (Data from U.S. Department of Labor Mine Safety and Health Administration.)

the realm of knowledge of proven facts that can be used to make an order-of-magnitude improvement in safety.

It is the purpose of this book to make these connections, to move from using negative data to using positive data to make bulk-materials handling by conveyor safer. That way, lives can be saved and the environment better managed while improving productivity and profit.

By 'connecting the dots' between indirect costs —once thought of as impossible to quantify—and reality, we can now calculate **Return On Conveyor Safety™** (**R.O.C.S.™**). This will ingrain a safety culture and improve maintenance activities to make a significant improvement in conveyor safety.

Safety, Defined

Safety, as used in this book, is the continuous process of mitigating the risk of personal injuries—and with it the related losses of property and income—through a variety of management, engineering, and awareness strategies.

Safety is a common noun with several meanings, such as: freedom from harm or danger, the state of being safe, the state of not being dangerous or harmful, or a device designed to prevent injury, property loss, or limit the operation of a machine. Safe is an adjective used to describe things that are protected from or not exposed to danger or risk, or not likely to be harmed or lost.

While the term safety is often used in absolute terms, it must be recognized that it is impossible to be '100 percent safe 100 percent of the time.' By using the concept of safety in absolute terms, we set an unrealistic goal. Doing so treats safety as a 'feature' gained simply by specifying compliance with rules and regulations.

Instead, safety is a 'benefit' derived from the organization's culture and from the proper design, operation, and maintenance of the equipment and systems, including belt conveyors.

Regulations and regulators are often given credit for a reduction in health and safety incidents. But anybody that works with regulation compliance knows that regulations are often vague and/or outdated. Compliance is subject to wide variations in interpretation. Relying solely on enforcement of regulations to improve safety is a reactive and inefficient approach. Absent

Is it 'Safety First' or 'Production First'?

It is common to enter a facility and see a catchy slogan along the lines of 'Safety First' or 'Zero Harm,' emblazoned on a poster or banner near the entry. At first glance, these seem noble proclamations, but often the message disappears quickly in the clutter, noise, and disarray of the facility and the actions of management.

The problem is this: Safety does not really come first.

Any business is—and must always be—most concerned with the reason it is in business—to make money by producing a saleable product or service. In other words, economically feasible production is the priority; this goal necessarily comes first. That is true in all industries and all occupations, from delivering papers to making cars, or from running a neighborhood bakery to operating the world's largest cement plant. A plant that is not primarily concerned with production will not be in business long. Other plants, other methods, and other economic forces will quickly drive it out of business.

So if the plant is dedicated to production, where does safety come in?

Is there anyone who is dedicated to safety? That answer is and must be the engineers who design the equipment and process, and as importantly—if not more so—the individual worker who, in the daily work, makes choices that will affect personal safety and the safety of others. These safety decisions will have significant effects on bottom-line results of the operation; consequently, managers at every level in the organization should be concerned with safety.

Taken literally, 'safety' is an absolute term. It is not reachable and workers instinctively know that. If regulations, a certain portion of industrial operations would not take even minimum safety precautions, but since the rise of occupational health and safety regulations beginning in the 1970s, the number of safety regulations has increased a hundredfold while the fatal accident rate has remained relatively unchanged.

It has long been established that warnings and administrative rules are among the least effective means of mitigating hazards and improving safety. If this 'safety by edict' methodology—thou shalt not put your hand into the machine; thou shalt wear thy protective equipment—is effective, why are there still industrial accidents? Certainly no one was ordered to have an accident.

By looking at safety as a benefit, rather than a feature obtained by management edict or regulatory requirement, we begin to change from the outdated belief that workers cause most of the accidents due to at-risk behaviors. By applying current best practices, understanding human nature, and changing our approaches to design and training, we can proactively take advantage of the well-established relationship between safety, productivity, and profit.

Every System is Perfectly Designed…

'Every system is perfectly designed to achieve exactly the results it gets.' That remark is commonly attributed to Dr. Paul Batalden, M.D. While Dr. Batalden was speaking about healthcare, his remark might just as easily be applied to conveyor systems, or even safety systems.

Conventionally designed belt conveyors are designed perfectly to produce what they now produce—fugitive material, short component life, cleanup labor, injuries and accidents, mistracking, waste, and high maintenance costs.

Most systems—and even belt conveyors—are so complex that the law of unintended consequences takes over. Complexity does not necessarily improve safety or productivity. There is no way you can anticipate every interaction between people and machines. In dismantling an entire organization to restructure it, you are as likely to create new dysfunctions as to fix the old problems.

In his book, *Five Hidden Mistakes CEOs Make,* leadership consultant Tom Northup added this thought:

absolute safety is the end goal and the manager or co-workers are not perfect, the conditions are set for failure. Any deviation—no matter how small—from absolute safety through unsafe actions, failure to enforce policies, or ignoring hazards can destroy a worker's belief in the slogan or the company's commitment to it.

In reality, safety is a continuous improvement journey. Perhaps slogans should reflect human nature and the need for providing needed goods and services safely, giving everybody a reachable and incrementally possible goal of 'Think Safer.'

In the case of belt conveyors, there is no debate about which comes first. The reason they exist is the need to move large quantities of bulk materials for purposes of production. Once that need is identified, quantified, and the options explored, then the operation sets about doing it as cost-effectively and safely as possible. That is where conveyors come in. The reason conveyors are used is because conveyors are often the lowest cost-per-ton method to transport large quantities of bulk materials and secondly, because they also can be the safest way.

As this book will note, safety improvements—for conveyors, and otherwise—can have a great payback for a business in terms of productivity, operating income, and as value for shareholders, including increased share price. The philosophy for any plant must be: 'Let's be productive, but let's do it safely.'

That makes our mantra: **Production Done Safely™**.

Even in that battle cry, production comes first, and safety is attached, but secondary. That reflects the economic realities of business—the real world. That makes it a slogan managers and workers can understand and embrace—all will know it represents the real corporate commitment!

> All organizations are perfectly designed to get the results they are now getting. If we want different results, we must change the way we do things.

He continues:

> Right now, your company gets the results —good or bad—that it was designed to get. If your vision of the future differs from your current situation, if you want to get better results, then you must change the way you do things. If you don't, how can you expect results that are any different from what you've already achieved?

Production Done Safely™

Work—especially work in industrial bulk-materials-handling operations—has risks. The job for workers is to manage those risks, reduce those risks, and eliminate those risks. Even a culture that preaches 'Safety First,' that vows workers are the most important resource, knows that when push comes to shove, the plant remains—and should be—dedicated to production.

But the challenge for the engineers and workers and their managers is to get **Production Done Safely™**.

There is unconsolidated, yet clear, evidence that companies that value safety have higher productivity and profit than those who focus on lowest cost production at the expense of safety. This volume will promote and demonstrate the value of belt-conveyor operations—in the handling of bulk materials—done cleaner, safer, and more productively, in the form of **Production Done Safely™**. In addition, this book will offer the methods and best practices to achieve those ends.

Production Done Safely™ is the rational objective for the continuation of operations for the continued profitable return to the company, for the continuation of wages to the workers with the resultant benefits to their community, and for the continued health and well-being of those workers.

The path to success is **Production Done Safely™**.

CLOSING THOUGHTS
Conveyors and Conveyor Safety

So how does this **Production Done Safely™** mantra or vision fit into a book about conveyors and conveyor safety? The answer is this: Because it is concerned with production first, the plant must be committed to make its conveyors as safe as possible.

The reason belt-conveyor systems are built and operated is to deliver the necessary quantity of bulk material into a process. In many cases a belt conveyor is used instead of or to replace another form of haulage. The use of the conveyor typically does improve safety. But the investment in a belt conveyor most likely would never be justified if it did not hold the promise of a lower cost per ton delivered. Consequently, it is obvious that the real justification for the use of the conveyor is production; that is, production done more cost-effectively and more efficiently.

So how do workers and equipment engineers make things safer? They do so by designing out the risk, and making it as difficult as possible to do something that is risky or unsafe.

The reason Martin Engineering has written this book is to show the ways that belt conveyors can be operated, maintained, built, and designed to eliminate or otherwise control the risks. This is done by showing danger areas, unsafe behaviors, and offering suggestions for design and cost justification. This will make the acts of production safer for all who must work on and around belt conveyors.

For belt conveyors, the continuing mission of this book is **Production Done Safely™**. ⚠

Section 1

HAZARDS AND DANGER AREAS

1

Section 1

INTRODUCTION

The Hazards of Belt Conveyors

A belt conveyor is a large rubber band, stretched at high tension and threaded through a maze of moving parts and pinch points. The belt moves at speed through this structure, carrying high volumes of loose cargo of various natures including sticky, abrasive, dusty, or corrosive. The conveyor is exposed to harsh industrial environments and random weather conditions. After installation, the conveyor generally receives little maintenance and less consideration. All of these circumstances combine to create a variety of hazards that can cause injury or death to an untrained or unwary worker.

It seems reasonable to assume that everyone knows that belt conveyors can be dangerous. Particularly, people who work around conveyors should know just how dangerous they are. But in spite of this knowledge, workers are still maimed and killed by conveyors every year.

To prevent these incidents, plant management and regulatory agencies have tried signage, edicts, and the establishment of safe work procedures to ensure worker safety. Signage notifies workers of danger points and unsafe practices. Edicts typically tell workers areas to stay away from and/or forbid the performance of specified unsafe tasks. Safe work practices tell workers how to execute their appointed duties. Together, these precautions would seem to be effective methods of protecting the workers.

But in the Real World

Reality tells us something different. The hazards presented by belt conveyors areevidenced by conveyor accident statistics from industrial operations around the world.

During the ten-year span between 2002 and 2012, there were 91 belt conveyor-related fatalities in the United States. Martin estimates 28 of these fatalities—roughly 30%—were reported in mines by the Mine Safety and Health Administration (MSHA); the remaining 63 were recorded by the Occupational Safety and Health Administration (OSHA) in other industries. In addition, OSHA reported 378 belt conveyor-related injuries in that same timespan.

Around the world, there are similar types and numbers of incidents. The statistics for some regions are a little less accurate and harder to find, as local reporting and tabulating requirements may be less well-defined, and so incidents are perhaps less well-tracked and harder to research. But evidence and anecdotes indicate there are significant problems in safety for those who must work on or around belt conveyors.

These numbers show existing conveyor-safety measures—the signs, edicts, and safe work practices—are not enough to protect workers. Given this information, one can only assume one of two things is happening; the prescribed safety measures are not robust enough, or the employees are not following them.

The Way the World Works

When an accident occurs at a place of employment, the atmosphere and attitudes are understandably changed—at least temporarily.

Afterward, there was an elevated awareness of safety throughout the facility. There were new signs, memos, letters, and announcements. There may have been new precautions mandated, and new equipment installed. Depending on the severity of the incident, standard procedures may have been altered. Shortly after the incident, there were choruses of 'Never again' or 'Not on my watch.'

Depending on how good a company is at maintaining that posture, the caution level of workers may stay high for a considerable time.

Until the Next Accident

A new accident draws the attention of workers and management. A new set of signs and other communications will be released and new procedures will be implemented. The entire company becomes focused on the new incident.

There is a considerable likelihood that this 'new' incident will make everyone forget the 'old' incident. While the procedure to correct the 'first' accident may be robust, a worker may forget about it because it is out of mind, or it is hidden in stacks of papers concerning the 'new' accident. When the wall is covered with safety signs, it begins to look like another wall after a while. This is how what was a robust solution can become ineffective after time.

If even the best safety precautions can fail over time, imagine how much more quickly a poorly thought-out and poorly implemented solution will fade.

Root Causes of Accidents

Many injuries are the result of a choice between multiple options based on conflicting inputs. Workers do not go to work thinking they are going to make a choice to be injured, but injuries still happen. When a worker enters an unsafe area or commits an unsafe act, there are three things that enter the worker's subconscious mind. The worker has an understanding of the way the world works, is focused on completing a task, and has an expectation of a safe result based on past experiences. Subconsciously, the workers are often torn between conflicting priorities of production and procedures. Humans are so predisposed to want to please the boss that even though safety is preached, production at any cost is what is practiced.

This understanding of 'the way the world works' is the knowledge that the worker brings to the situation. It includes the basics of physics—gravity, velocity, other mechanical functions, and the safety hazards of the specific equipment in the facility. This is why task training and safety briefings are conducted. These sessions represent an attempt to inform the worker of the dangerous areas and the unsafe practices associated with a task.

1

Looking at the Sources of Conveyor Accidents

The following section is a summary of the most common danger zones and unsafe practices associated specifically with conveyor belts. It is derived from safety statistics, industry standards and regulations, and the vast experience of Martin Engineering personnel who work on or around belt conveyors every day, around the world.

These chapters are also focused on the unsafe areas of a conveyor, and the unsafe practices workers may use around a conveyor. If workers have a better understanding of the way the world works, they will have a better awareness of the danger zones of conveyors and unsafe practices. Knowing the dangers will help the workers avoid the hazards of belt conveyors, so they can go home safe every day. ⚠

1

Chapter 2 Danger Zones of Belt Conveyors

INTRODUCTION
Causes of Injury

Belt-conveyor systems have been the workhorses of the bulk-materials-handling industry since 1795. Like horses, they can do an amazing amount of work. Their very function is to transport large quantities of bulk materials from one place to another.

Much like domesticated horses, conveyor-belt systems are not predisposed to hurt workers. But because they are powerful devices, conveyors can and will kill or maim workers if not given the proper respect.

A worker should treat both a horse and a conveyor with respect because of the potential for energy to be unleashed on a worker. Even a short and simple conveyor driven by only a single-horsepower motor poses dangers to workers. Given that the typical bulk-handling conveyor is driven by a multiple-horsepower motor, the danger to a worker is significantly increased.

In the next two chapters, we will discuss some of the specific dangers of a belt conveyor. First, we will review how a conveyor can be dangerous. The following chapter will examine some unsafe work practices which can put a worker in danger. The chapter after that will present a number of safe practices around conveyors that help to keep a worker safer.

The Danger Zones

The Conveyor System Itself

A conveyor system is often a massive, complicated, and powerful piece of equipment. (**Figure 2.1.**) Usually a conveyor is a rubber belt set on rolling idlers, wrapped around gigantic steel drums at each end, and driven by a large motor. As such, it presents enough danger zones that the entire conveyor system should be considered a hazard.

Given that the conveyor moves material a predefined distance, over varying terrain, and through various elevations, the amount of power encapsulated in the system varies by application. A simple conveyor carrying 100 metric tons per hour [≈110 tph] for 30 meters [≈100 ft] over flat terrain uses 4 kilowatts [≈5 Hp] of power. The size, strength, and power demands of conveyors go up from that relatively short, small, low-powered unit. A larger conveyor carrying 1,000 metric tons per hour of material uphill over 1.6 kilometers [≈1100 tph over ≈1 mi] will require a drive system with a motor on the order of 375 kilowatts [≈500 Hp]. While the specifics of how much energy is in the system vary from conveyor to conveyor, it is still a massive and potentially deadly amount of energy. It has the power to elevate and carry tons of material; it can easily destroy a human.

Most conveyors are engineered with the ability to start remotely. Many conveyors are designed with complex control and safety systems as integral parts of a process. Complexity does not necessarily guarantee safety. The system may go from dormant to active at any time, at the push of a button, and that ability can suddenly catch a worker unaware, leading to serious injury or death.

The Cargo

The material on a conveyor can be just as dangerous as the conveyor-belt system itself. (**Figure 2.2.**) In some cases, the material may be flammable, radioactive, carcinogenic, explosive, toxic, or extreme in temperature.

The hazards to a worker may not be consistent across the facility. An example would be, one conveyor in a cement plant may have a safe material on it, while another, in a different part of the process, may have a high concentration of silica.

A worker could be injured by the impact from a lump of the conveyed material or the weight of the large quantity of material spilled or discharged from the belt. All standards require guarding against falling bulk materials but, such guarding is seldom seen except over well-traveled roads and walkways.

In addition to the potential material hazards, a worker can be engulfed by the material stream. A worker can also be trapped between the material stream and a fixed object. Of the fatalities recorded by the Mine Safety and Health Administration (MSHA) in the United States between 1995 and 2011, Martin estimates five percent were caused by engulfment in material.

Figure 2.1.

A belt conveyor system is a massive, complicated, and powerful piece of equipment.

Figure 2.2.

Belt conveyors move loose material at relatively high volumes and high speeds.

1

The Belt

A typical conveyor belt moves at a relatively constant speed, commonly running between 0.5 to 10 meters per second [≈100 to 1,968 fpm]. (**Figure 2.3.**) An Olympic sprinter has a reaction time of 0.18 seconds—roughly one-fifth of a second—when at the starting line totally focused on the race. If this sprinter becomes tangled in a conveyor belt traveling 1.5 meters per second [≈300 fpm], the athlete will be carried 0.27 meters [≈10.6 in.]—the length of a ruler—before the sprinter ever realizes what has happened. Research shows that when distracted, reaction times can increase by a factor of two or three. Some safety sites list the reaction time for a conveyor worker as high as 1 second. In addition, the natural human reaction when holding a tool is to tighten the grip and try to retrieve the tool, starting the reaction-time process all over again.

Figure 2.3.

Belt conveyors make many industrial processes possible.

Points of Interest: Pinch, Nip, and Shear

One form of a conveyor hazard is commonly referred to as a pinch point. Pinch point is a rather universal name for a variety of hazards, including those also called nip points and shear points. The definitions and distinctions for these vary; in many cases, these names are used interchangeably.

A pinch point is produced when two objects come together; and there is a possibility that a person could be caught or injured when coming in contact with that area. In its fact sheet on the topic, the Michigan Occupational Safety and Health Administration (MIOSHA) defines a pinch point as

> ... any point at which it is possible for a person or part of a person's body to be caught between moving parts of a machine, or between the moving and stationary parts of a machine, or between material and any part of the machine.

A pinch point can be created by rotating motion, reciprocating motion, transverse motion—that is, movement in a straight, continuous line—or actions that involve cutting—including rotating, reciprocating, or transverse motion—punching, shearing, or bending.

Pinch points commonly impact fingers and hands, but can impact any area of the body. The injury resulting from a pinch point could be as minor as a blister or as severe as amputation or death.

It is a challenge to see if there is a difference in definition between pinch, nip, and shear points. For our purposes we offer the following definitions:

- **Pinch point—**A pinch point is any location where a person or part of a person's body can be caught between two or more moving mechanical parts, or the bulk material and a moving part.
- **Shear point**—A shear point occurs where the edges of two machine parts move across or close enough to each other to cut a relatively soft material. In a typical shear point hazard, one part moves while the other part can be stationary or moving.
- **Nip point—**A nip point is a hazardous area at which an element of the conveyor machinery moving in a line or rotating meets another element which is either rotating or moving in a line in such a manner that it is possible to nip, pinch, squeeze, or entrap objects coming in contact with one of the two elements.

In-Running Nip Points

The most common and significantly dangerous type of hazard on a conveyor is the 'in-running nip point.' This is where the machinery motion acts to hold and/or draw in a human extremity or other object that has come into contact with the components.

Nip points exist where material—such as a conveyor belt—enters a gradually narrowing opening, for example, and the forces are strong enough to pull body parts, such as fingers, hands, arms, and hair, into the opening. In-running nip points on conveyors usually involve a moving belt and a rotating component such as an idler roller or a pulley.

At the very minimum, a worker—even with world-class reaction time and totally focused on the danger of a conveyor—on the danger of a conveyor—may inadvertently be caught in the nip between the belt and a carrying idler and not be able to react fast enough to avoid being drawn in.

A 'regular' worker—one who is not a world-class athlete—would require a longer time to react. For simplicity's sake, let us assume it would be twice the reaction time, so the worker would be pulled twice as far. The worker will have the potential to strike many more components, or be pulled farther and harder into the first one.

Some standards maintain that if the belt is lightweight and there is at least 50 millimeters [≈2 in.] of free space above the belt, the pinch point created by the belt and idler does not pose a hazard and does not require guarding.

In addition to the potential to carry away a worker, a conveyor belt acts like a giant grinder. Conveyor belts have been known to cut through steel structure. The human body is far softer than steel, so the belt will cut through flesh very quickly.

A ripped belt can also present a danger to a worker. If there is a flap, cable, or protrusion in the moving belt, that object is traveling at the same speed as the belt. This offers the

The 2007 publication *Safeguarding Equipment and Protecting Employees from Amputations* available from the United States' Occupational Safety and Health Administration (OSHA) notes,

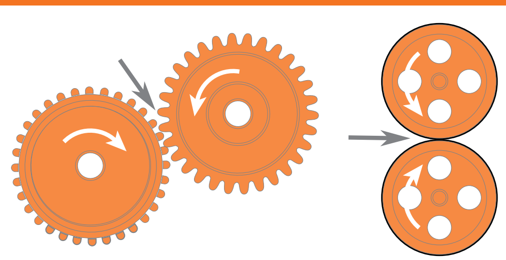
> In-Running Nip Points, also known as 'pinch points,' develop when two parts move together and at least one moves in rotary or circular motion. In-running nip points occur whenever machine parts move toward each other or when one part moves past a stationary object.

In-running nip point hazards are most often caused by the rotating and translating parts on the conveyor. These parts may be touching or in close proximity. Regulations in many countries consider a separation of 50 millimeters [≈2 in.] or more a mitigating circumstance, where technically it is not a nip point and so does not require guarding. This is often the logic applied to the sealing portion of the load zone when the chute steel ends 50 millimeters [≈2 in.] or more above the belt, and, therefore, does not require guarding. A similar conclusion is applied to the carrying section where if the belt can be lifted 50 millimeters [≈2 in.] or more, the interaction between the belt and the wing rollers of the idler is technically not a nip point. Using this definition is dangerous and should be discontinued as only the lightest of unloaded belts can be lifted to release a trapped person or object. A body part drawn into such a gap probably cannot be withdrawn until the conveyor stops.

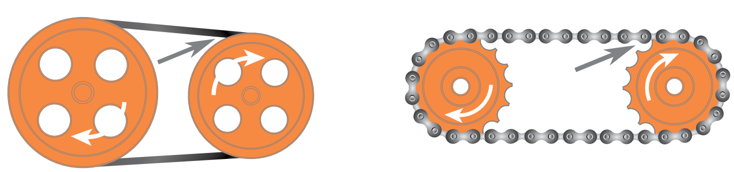
Places like return rollers and pulleys of all types in contact with the belt create in-running nip points where parts of the body may be caught between or drawn into the nip point and crushed, mangled, or severed. As a result, these should be guarded to prevent any portion of a worker entering the danger zone. If components rotate—or have the potential to rotate—in both directions, this creates two in-running nip points—one from either side—and so should be guarded to prevent approach from either direction.

Final Points: A Nip by Any Name…

No matter what they are called, nip, shear, and pinch points all represent hazards. They should be designed out of the system where possible, and where it is not possible, they should be guarded effectively. In addition, workers should be trained to stay away from the danger zones these points create, and to immediately report unguarded nip points or other unsafe conditions to their supervisors.



Common nip points on rotating parts



Nip points between elements and parts with longitudinal motion

1

potential of a moving object to be traveling along the length of the belt, but outside of the controlled area that a belt normally travels. If a worker is struck, injury or death may occur.

A conveyor belt traveling outside of the intended path is called mistracking. If a belt is mistracking, it is not where it is supposed to be and not in the path a worker would expect. Any large moving component operating where it is not supposed to is a hazard.

As a conveyor belt moves, there is the potential for the belt to gather an electrical charge from the environment. If a worker comes in contact with this charge of electricity, the built-up static electricity will discharge through the worker. Under normal circumstances, this shock is harmless. Shuffling across a carpet can generate from 10 to 25 millijoules (mJ), which is just one or two percent of a lethal jolt. It typically requires at least 1 mJ to generate a shock you can feel, 10 to 30 mJ to make you flinch, and 1,350 mJ to kill you. Fatal accidents from static electricity are very rare but the 'startled' reaction to a static shock can cause a worker to lose balance, fall, or otherwise put others in harm's way. This can be as dangerous as an open line of voltage.

Stored Energy

When a conveyor belt is moving, there will usually be more tension on the carrying side. If the conveyor is merely stopped and de-energized, that tension will remain in the belt in the form of potential energy stored in the stretched belt. A system under tension will always try to approach equilibrium; that is, it will try to release that energy.

If the gears in a gearbox have stripped, or the friction between the pulley and the belt is insufficient, the belt may release all of the tension with the conveyor powered down and locked out. This release will usually come in the form of a pulley slip. This occurs when the belt slips around the head pulley to equalize tension. The belt will move suddenly. The distance the belt will move is proportional to the amount of tension stored and the belt modulus. If a worker is on the belt or close enough to be pulled in during this sudden release of energy, injury or death can occur. Of the fatalities recorded by MSHA between 1995 and 2011, Martin estimates two percent were caused by stored energy.

Figure 2.4.

The drive system contains some of the rotating components seen on a belt conveyor.

Rotating Components

Many of the moving parts on a conveyor belt system are rotating components. (**Figure 2.4.**) These parts include idlers, drive shafts, pulleys, and speed sensors. Items rotating at a high speed pose entanglement hazards as well as pinch-point hazards. In addition to the inherent hazard of a rotating component, the presence of the hazard may not even be visible. When a component rotates at high speed or under certain stroboscopic lighting effects, a rotating component can appear to be standing still. This strobe effect can create an unexpected nip or pinch hazard.

In addition to the rotating hazards, any moving part has the potential to create frictional heat. If enough heat is generated, a burn could result if a worker were to come in contact with the hot surface.

Pinch Points

There are many items the conveyor belt actually touches. These include the drive pulleys, the snub pulleys, and the idlers. There are also many items that come near the belt. These include the structure, the chute wall, and deflectors. If a worker's limb travels with a conveyor belt, it will meet one of these items. The limb, as well as its attached worker, will become trapped between the belt and the obstruction. As neither the belt nor the obstruction is very flexible, the captured appendage can be crushed. This is called entrapment. (**Figure 2.5.**)

In addition to direct contact with the belt by human flesh, the same result can be achieved with a tool. A shovel will be pulled into an entrapment situation and will pull the worker holding the tool into the situation before the person can let go of the tool. The same is true of loose-fitting clothing.

Drive belts attached to conveyor drive motors can also present pinch-point hazards.

Utilizing MSHA records in the years between 1995 and 2011, Martin estimates there were 57 fatalities in the mines of the United States involving conveyor belts. Of these fatalities, Martin estimates 61percent were the result of a worker coming in contact with one of these pinch points.

Takeup System

Belt conveyors require tension on the belt to prevent the belt from slipping on the drive pulleys. The two most common methods of providing tension are a gravity takeup or a mechanical takeup. Other methods such as hydraulic or winch systems, often utilizing wire ropes to transmit tension, are common underground and on overland conveyors. Basically, each method acts to 'extend the structure' which 'takes up' belt stretch and maintains the belt tension required for the motor torque to be converted into belt tension.

A gravity takeup works by pulling down on the belt with a weight. (**Figure 2.6.**) A gravity takeup can present many hazards. The most obvious hazard is the fact that there is a heavy weight, often in the range of 2,200 to 22,000 kilograms [≈5,000 to 50,000 lb], suspended above ground by a moving conveyor belt. If the belt or a takeup component were to fail, the weight will fall from a great height. This will crush a worker who is unfortunate enough to be below it. The weight on a gravity takeup slides upward upon the startup of the conveyor system, moving as much as 6 meters [≈20 ft]. This large mass moving upward very rapidly can also create a variety of hazards for a worker positioned nearby. These hazards include blunt trauma from being struck, entanglement in the mechanism, or crushing if a failure occurred. The takeup weight or tension is one of the inputs that is often changed without adequate calculation or knowledge of the consequences and the severity. Adding too much weight (tension) to the belt can cause catastrophic belt or component failure.

A mechanical takeup (**Figure 2.7.**) functions by pulling the tail pulley away from the head pulley to tighten the belt. The tail pulley

Figure 2.5.

The pinch point between the belt and a carrying idler can lead to an entrapment injury.

Figure 2.6.

A gravity takeup uses the force of gravity on a suspended weight to maintain belt tension.

Photo courtesy of United States Mine Rescue Association.

Figure 2.7.

This screw takeup adjusts belt tension by moving the tail pulley away from the head pulley.

1

is usually set on screws, and the screws are turned to pull the pulley back. The screw threads might be unguarded or located in an unsafe position near a nip point. Most mechanical takeups do not have a tension-indicating feature and over-tensioning the belt is a common root cause for splice failure. Just as with a gravity takeup, there is always potential for mechanical failure. The 2003 publication, *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*, jointly produced by Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) and Commission de la santé et de la sécurité du travail (irsst), both of Quebec, reported that four percent of fatal accidents around conveyors occurred while adjusting the takeup or tracking the belt.

Hazardous Accessories

Accessories to a belt-conveyor system can offer hazards themselves.

Conveyor magnets produce a strong magnetic field that will interfere with pacemakers and other electronic medical implants. These magnets may also attract any metallic inserts or prosthetics. Cross-belt analyzers may include a radiation source. Accessories such as air tensioners may have an onboard reservoir holding quantities of compressed air under pressure. The plant's compressed-air system itself may also present dangers to workers. Actuators for gates and diverters are often operated remotely and usually considered guarded by location.

Figure 2.8.

The structure to hold the weight of a conveyor is usually a complicated and robust construction.

Structure Failures

Belt conveyors are extremely heavy and massive systems. (**Figure 2.8.**) The structure to hold the weight of a conveyor is a complicated and robust construction. As a construction, parts can fail due to being undersized, overstressed, or compromised by the environment. If a failure occurs to a critical part and a worker is near or below the conveyor when this happens, the worker could be crushed.

Catwalks can also be the site of a structural failure. If a walkway gives way, an unlucky worker on that catwalk may fall a great distance, or a worker below the catwalk may be hit. Holes in the catwalk can cause injuries and uneven catwalk surfaces can cause tripping.

The construction of catwalks is subject to various standards. Some standards specify walking surfaces should have a coefficient of friction of 0.5 with soles of common safety boots.

Whether a structure falls on a worker, or a worker falls onto or into a structure, serious injury or death is a possibility. Of the fatalities recorded by MSHA between 1995 and 2011, Martin estimates five percent were caused by such a failure during setup or operation.

Falling Components and Material

As mentioned before, belt conveyors move material vertically as well as horizontally. The elevation change will raise the cargo, as well as the conveyor's components, off the ground. Any item, whether it is material, a hand tool, or a conveyor component, has the potential to fall on a worker, building, or another conveyor or process machinery.

Conveyor-belt components are also susceptible to damage from the moving belt. A mistracking conveyor belt can cut through the hanger mount holding an idler to the stringer. If this support bracket is cut, the idler can fall and injure anyone below it. Falling idlers have been known to penetrate roofs and injure or kill.

Of the fatalities recorded by MSHA in the United States between 1995 and 2011, Martin estimates two percent were attributed to material falling on a worker.

Spillage Around the Conveyor

As detailed above, conveyors are very powerful machines, utilizing large motors and applying large quantities of power, and when stopped, storing significant potential energy in the belt and cargo. One of the biggest dangers of a conveyor to a worker is anything that can bring a worker close to that conveyor's power.

Many of the fatalities around conveyors have happened when a worker was cleaning material from around or from the components of a conveyor system. Material that falls from a conveyor belt, called spillage, needs to be removed; otherwise, the buildups interfere with system performance and component service life. (**Figure 2.9.**) The process of cleaning may put a worker in proximity to a dangerous machine. The need to shovel, sweep, or hose off accumulations of loose material, washing them into drains, or scooping them up to return to the conveyor puts the worker within arm's length of the conveyor, and often closer.

The tools used for cleanup increase the risk for the worker. The shovel and broom are long-handled extensions of a worker's arm, and the act of cleaning under conveyors puts these extensions closer to rolling components that can catch the tool and pull it, and the attached worker, into danger.

The very spillage that the worker is attempting to clean can create trip hazards. Spillage can also obscure a hole in the floor on which a worker can trip or fall. By themselves, these trip and slip hazards can cause injury if a worker falls.

The danger from a fall is amplified by the proximity to a moving conveyor belt. If a worker were to fall into a moving conveyor, serious injury, and even death, may occur. Though the accident recording agencies and insurance companies may classify the injury source as the fall, the root cause of the injury remains the conveyor. In the United States, the Occupational Safety and Health Administration (OSHA) reports that 15 percent of general industry-wide accidental deaths are from slips, trips, and falls.

Spillage can also present dangers. A pile of spillage on an emergency-stop switch can prevent the switch from working. That same pile can change a hazard from being guarded by location to an exposed hazard. Spillage can trap moisture or be corrosive; if this spillage is on a conveyor component, it could destroy the integrity of the component without showing visible signs. If this component is load bearing, a catastrophic failure can occur.

Air Quality and Dust

When material falls from a conveyor and lands on the ground, it is called spillage. When material leaves a conveyor and becomes airborne, it is called dust. (**Figure 2.10.**) Airborne dust can cause numerous health risks ranging from material buildup in the lungs, to explosion, and slowed worker reaction times.

Figure 2.9.

Accumulation of spillage can interfere with conveyor system performance and component service life.

Figure 2.10.

Dust is fugitive material driven or carried off a conveyor system by currents of air.

1

1

- **Respirable dust**—Whenever a dust particle is smaller than 10 microns, if it is breathed in, it can stay in the lungs. As more dust is breathed in, more dust particles will accumulate in the lungs. The human body may not be able to deal with this material. The best case would involve decreased breathing capacity. The worst case would be a debilitating and incurable lung disease such as Silicosis or Pneumoconiosis (black lung disease). Other bulk-material dusts and fumes can be poisonous (for example, lead) or a cause of respiratory cancers (for example, asbestos).
- **Explosivity**—The dust from many materials can become explosive if dispersed, confined, and ignited. This explosion could represent massive capital losses as well as a potential for loss of human life.
- **Slowed reaction time due to protective equipment**—As stated above, conveyors can injure a worker very quickly. The personal protective equipment (PPE) used to protect a worker from exposure to respirable dust decreases reaction time and visibility. These fractions of a second could represent the difference between a close call and a fatality.

Figure 2.11.

Many conveyors feature close quarters or confined spaces, which can make service difficult.

Figure 2.12.

Conveyors are often employed to elevate material; and so conveyor workers are often required to work at heights.

Image courtesy of CDC/Theresa Roebuck.

As bulk materials handled on conveyors are one of the sources of dust, the entire conveyor is a potential hazard.

Confined Spaces

Many conveyors are fed from hoppers or enclosed chutes. (**Figure 2.11.**) According to United States OSHA regulations in *29 CFR 1910.146*, any enclosure that "is large enough and so configured that an employee can bodily enter and perform assigned work;" "has limited or restricted means for entry or exit;" and is "not designed for continuous employee occupancy" is defined as a confined space. The personal dangers of a confined space are limited mobility, lack of oxygen, buildup of waste gasses, and the potential for explosion.

Most countries have similar regulations to control work in confined spaces.

Even so, Martin estimates seven percent of the fatalities recorded by MSHA in the United States between 1995 and 2011, happened in a confined space.

Working at Heights

In addition to moving material a horizontal distance, many belt conveyors are used to change the vertical position of material as well. (**Figure 2.12.**) As this elevation change could put some conveyor components off the ground, maintenance on these components creates the potential for an injury due to a fall from a great height. Depending on the height and circumstances, a fall could even result in death.

Of the conveyor fatalities recorded by MSHA in the United States between 1995 and 2011, Martin estimates nine percent were caused by a fall.

Maintenance Work

Belt-conveyor systems are massive and complicated systems with thousands of moving parts. (**Figure 2.13.**) By definition, a moving part will eventually fail and need to be replaced. Some of the components on a conveyor system that require maintenance are rollers, idlers, belt splices, couplers, motors, lagging, belting, and belt cleaners. There are usually many more items that require maintenance, depending on the system design and the accessories applied to the conveyor.

The life of a moving component can be extended by regular maintenance, but maintenance or replacement will place a worker in close proximity to a very dangerous piece of equipment.

The IRSST / CSST publication *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones* reported 26 percent of serious or fatal conveyor accidents happen during maintenance.

Lifting

As many conveyors lift and carry large amounts of bulk materials from one location to another, there is also the potential need for workers to lift and carry heavy loads as well. (**Figure 2.14.**)

Conveyor components need to be carried to the conveyor, or up stairs, or over long inclines to transfer towers. Bulky, and/or heavy tools may need to be carried to the conveyor belt. Quantities of material must be transported during a sampling process.

These chores offer the potential for many strain or lifting injuries known as musculoskeletal injuries. These injuries are often difficult to diagnose, treat, and have long recovery times. The potential for injury becomes greater when stairs or ladders are involved. If a worker is holding onto a load, they cannot grasp railings or stabilize themselves in any way. If a worker is carrying a load with both hands, the worker cannot establish the three points of contact necessary for safe ascent and descent.

Electrical Hazards

Conveyor belts are normally powered by drive systems incorporating electric motors utilizing from 480 to 1,000 volt alternating current (VAC) of potential. (**Figure 2.15.**) Occasionally, conveyors and their immediate vicinities are wet, providing an enhanced path from an electrical source through the human body to ground. Many controls and power tools operate at lower voltages but can still cause fatal shocks.

The minimum current a human can feel depends on the current type—alternating current (AC) or direct current (DC)—and frequency. A person can feel at least 1 milliamperes (mA) (rms) of AC at 60 Hz, while it takes at least 5 mA for DC to be felt. At around 10 milliamperes, AC current passing

Figure 2.13.

Composed of many moving parts and operating in challenging industrial conditions, it is inevitable that conveyors will require maintenance.

Figure 2.14.

The size of many conveyor systems means individual components can be heavy to lift and awkward to handle.

Figure 2.15.

As they are driven by electric motors, many conveyors can pose electrical hazards to workers.

1

through the arm of a typical worker can cause powerful muscle contractions; the victim will be unable to voluntarily control muscles and cannot release an electrified object. This is known as the 'let-go threshold' and is a criterion for shock hazard in electrical regulations.

The current may, if it is high enough, cause tissue damage or fibrillation which leads to cardiac arrest. A sustained electric shock at 120 VAC, 60 Hz is an especially dangerous source of ventricular fibrillation because it usually exceeds the 'let-go threshold,' while not delivering enough initial energy to propel the person away from the source.

Because of the large amount of current used within a conveyor drive system, great care must be taken to prevent injury or death from this electricity.

Fire Hazards

The material conveyed by a conveyor belt system can be flammable. (**Figure 2.16.**) This is especially true when the material conveyed is coal, dry wood chips, or flour. If the material is flammable, any spark from an ignition source may light the entire material stream on fire. While this fire can represent large losses in capital by itself, the fire can also act as the catalyst for a dust explosion as well. If a rolling component becomes locked, the friction of a belt traveling across it will cause heat. This heat could ignite a material stream or airborne dust. A hot spot from a welder is dangerous for the same reason.

Figure 2.16.

Because they carry flammable cargo on a belt made of flammable elastomers, a conveyor fire can be a serious hazard.

Some materials have a tendency to self-ignite. If the material conveyed is one of these materials, it has the potential to start a fire.

If a fire starts, whether by the material or some other source, it has the very real possibility of setting the conveyor belt on fire and risking massive losses in money and lives.

Noise

Conveyor-belt systems tend to be noisy. Between the drive motor, the rolling components, the material striking or sliding along components, and the material displacing the air, there is a large amount of noise produced. (**Figure 2.17.**)

Figure 2.17.

The high volume of carried material combined with many rolling components creates conveyor noise hazards which can require the use of hearing protection.

Exposure to high levels of noise leads to permanent hearing loss.

In the United States, OSHA defines the noise levels that cause permanent hearing loss in *29 CFR 1910.95*, using the measurement of decibel levels. A decibel is the measure of pressure that a given sound source transmits through the air. On average, hearing damage occurs at prolonged exposure to 90 decibels (A scale), or dBA; this is the noise level created by heavy traffic.

A typical conveyor-belt system produces 70 dBA, but the noise levels can be higher, especially when the sound of material moving through chutes and landing on the belt is included. If the conveyor produces noise levels higher than that threshold, exposure to the conveyor noise will result in hearing damage.

The noise from conveyors can be a low frequency created by belt flap or belt-on-idler noise. This low-frequency noise can travel great distances, particularly over water, and is a source of discomfort to people working or living around conveyors.

Inadequate Lighting

In the United States, OSHA's *29 CFR 1926.56* has established minimum lighting requirements in foot-candles—a measure of the amount of illumination produced by a candle from a one-foot distance—for a variety of work environments. (**Figure 2.18.**) Like all industrial applications, indoor conveyors should be lit to 5 foot-candles or candelas [≈54 lux]. Outdoor conveyors must be lit to 3 foot-candles [≈32 lux]. For example, United Kingdom's Health and Safety Executive recommends an average 50 lux [≈4.6 foot-candles] with a minimum 20 lux [≈1.9 foot-candles] for rough work and 100/50 lux [≈9.2/4.6 foot-candles for work requiring attention to limited detail. Any lighting below the specified amounts is considered insufficient and hence a safety risk.

Poor lighting can be caused by two things:

1. Insufficient amount of lighting installed and/or
2. Decrease in lighting caused by the presence of airborne dust in the air or accumulating on the lighting fixtures.

Whatever the cause, a decrease in visibility around a conveyor belt can and often will reduce reaction times and so increase the risks. Anything that slows reaction times can lead to injury at the hands of the conveyor belt. A reduction in visibility can also make it more difficult to see the dangers that exist around a conveyor belt.

Night Operations

Due to plant production requirements, conveyor systems may need to operate at night. In addition to the dangers associated with a belt conveyor, operating the conveyor at night will add additional hazards.

Despite even the best lighting systems, the dark of night will reduce visibility around moving components. The darkness will reduce depth perception and hide obstacles and hazards.

If an injury takes place, the response time for emergency crews to arrive may be longer, as they must move at slower speeds over grounds that are dark and unfamiliar.

It becomes necessary to be more vigilant around conveyor belts after sunset.

Changes in Weather

Martin estimates 50 percent of all belt conveyors that handle bulk materials are installed outside. A conveyor residing outside is exposed to the prevailing weather of the area. This weather can offer additional hazards that must be considered. Snow, rain, or fog will reduce visibility. Hypothermia or frostbite can occur for workers who are exposed to low temperatures. High temperatures can cause dehydration and lightheadedness. High and low temperatures can also change the behavior of the working fluids in a conveyor system. The addition of water, in the form of rain, can turn normally firm footing into a slick surface with greater potential for slips. In cold conditions, water forms ice that amplifies this risk.

Ice and snow can also accumulate on overhead structures and can fall on workers. The additional weight of snow and ice can also add additional load to the structure. Ice may

Figure 2.18.

Many facilities operate conveyors at night, creating hazards from low visibility.

build up and temporarily inhibit the function of components—until that fixture suddenly breaks loose—resulting in sudden or unexpected actions.

Rain, snow, and ice can accumulate on both the carrying and return runs of the conveyor. Upon startup, these accumulations can cause significant messes in and around transfer points. In some cases the amount of snow or ice can cause the shutdown of a conveyor for cleanup which exposes workers to both the hazards of cleaning the conveyor and surrounding slippery surfaces.

1

Mobile Conveyors

In addition to stationary conveyors, many operations incorporate mobile conveyors. (**Figure 2.19.**) These might include radial stacker conveyors designed to pivot to build a stockpile and other moveable systems. These mobile conveyors offer the same safety risks as their stationary counterparts, but they also present additional risks due to their mobility. A mobile conveyor has the ability to bring the hazard to the worker, not the other way around.

An unexpected movement can crush a worker with the entire mass of the conveyor system. Pinch points that were covered at one time may be exposed at another time.

Of the fatalities recorded by MSHA between 1995 and 2011, Martin estimates four percent were related to a mobile conveyor.

Danger Zones External to the Conveyor

While not part of, or directly caused by the conveyor, there are external factors and conditions that can place a worker in danger from the conveyor belt. For example: an exit from the conveyor may lead directly into a traffic way; or dust blown off the conveyor can reduce visibility or get into eyes and breathing passages. While these items may have their own safety issues, their interaction with a conveyor belt creates the potential for injury or death.

Underground Operations

Many conveyors are underground. Maintenance on these conveyors carries the risks associated with the conveyor, as well as the risks from an underground environment. Those risks could include—but not be limited to—poor oxygen ventilation, explosive dust and gases, toxic gases (such as carbon monoxide and methane), and roof falls. A recent MSHA-recorded fatality involved a roof fall trapping a worker against a conveyor. The collapse of the roof caused the fatality, but the conveyor was involved.

Site-Specific Hazards

Many belt-conveyor systems are in place at mine sites. In addition to the conveyor hazards, a worker must be conscious of the hazards specific to the mine environment. The worker can be pulled into the mine hazard because of the needs of the conveyor for maintenance. These mine-specific hazards could include haulage traffic and the movement of other heavy equipment, rock-fall hazards, blasting dangers, and the hazards that arise from the large quantity of material extracted, moved, and stored in any mining environment. Site-specific training for contractors and casual visitors is now required by most regulations.

Worker Expectations

The expectation of a safe result despite using an unsafe practice can be identified by the phrase, 'I have done it this way before and have never gotten hurt.' Thus, the unsafe practice becomes a habit and is not given a second thought.

Figure 2.19.

Some conveyors such as this radial stacker are designed to move, which can create a risk for the unwary worker.

The problem with this train of thought is the worker begins trusting himself rather than the statistics. The odd thing about statistics is that the incident that is being studied will eventually happen if the act is repeated enough. If an injury occurs one percent of the time an unsafe practice is committed, it only takes 99 of these events to mathematically expect an injury. Working in unsafe conditions or at a facility with a poor safety culture, and when coupled with unsafe acts, makes it not a question of 'if' but 'when' an accident will occur.

Attractive Nuisance

As many conveyors are located outside and can be seen from adjoining property or public roads, they create what might be termed an 'attractive nuisance.'

In law, the attractive-nuisance doctrine indicates that a property owner who creates or permits to exist a dangerous condition attractive to children is liable for their resulting injuries, even though the injured are trespassers. The most common example of this is a swimming pool, but the doctrine could be applied to virtually anything on the property of the landowner. It has been applied to hold landowners liable for injuries caused by abandoned cars, piles of lumber or sand, and trampolines.

In the case of conveyors, non-employees—whether children or adults—might be tempted to climb the structure to observe the surroundings or to walk the walkway. Doing so, they risk coming into contact with moving parts and other hazards of the conveyor.

Even though attractive nuisance case law does not often apply to adults, it would be better to provide suitable barriers to keep out all visitors, rather than invite the lawsuits that the uninvited guest who suffers injury might bring.

It is not just the workers in the plant who are exposed to conveyor-related hazards. There are secondary hazards created by conveyors to the environment, animals, and people living or traveling in the vicinity of the conveyors—most notably noise and dust.

CLOSING THOUGHTS
Knowing the Hazards

While the belt-conveyor system is the central artery of most bulk-materials-handling operations, the actual design and safety concerns have not changed a great deal since their inception. There are many accessories to assist in safety, but a conveyor belt is still a dangerous machine.

A key to working with a horse and not being injured is to know the dangers. This is very similar to the way to utilize a conveyor and not be injured. This section should have assisted the reader in becoming aware of many of the specific physical dangers associated with conveyor. ⚠

1

Chapter 3

Unsafe Work Practices Around Conveyors

INTRODUCTION

In addition to all of the physical danger zones of conveyors, as discussed in the previous section, workers can be injured by their own actions or inactions. The most common unsafe work practices have been collected and shown below. As with the previous section, this list of practices is displayed in the order determined by the consensus of opinion of Martin Engineering employees who work with conveyor belts on a regular basis. The practices that are considered the most dangerous are listed first.

No one goes to work planning to get injured by performing unsafe acts. When performing accident investigations, the easy way out is to list the cause of the accident as an unsafe act. In reality, the root cause(s) is much more complex than a worker simply working unsafely. The conclusion that the single root cause of an accident was an unsafe act is taken from a hindsight point of view, and as we know, hindsight is perfect. The corollary is that foresight must then also be perfect. Therefore, asserting that an unsafe act was the sole cause of the injury means the worker knew ahead of time this act would result in an injury and did it purposefully.

Accidents are usually a result of a complex combination of probabilities and risk/reward decisions, not just a single unsafe act. One could say, except for the unsafe act, the injury would not have occurred. Just as logically it can be said: if there was a safer design; if there was adequate maintenance; if there was less pressure for production; if there had not been a time limit on the job; and so on and so on; the accident would not have occurred. Proper, in-depth accident investigations often uncomfortably draw attention to the company's safety culture, management, and conflicting rules and goals. Due to the complexity of these factors, this can result in the worker making a decision—in the heat of the moment—that is logical when all the external inputs and pressures are taken into account.

Things Managers Do to Put Workers in Danger

'Management by edict' is easy but ineffective. It is human nature to resist authority, and when rules get in the way of completing tasks they can become 'Stupid Rules' that everybody ignores. As designs and technology change, management needs to listen to workers and update safety rules and practices.

Today, many components can be designed to be safely or remotely serviced while the conveyor is in operation but the rules prohibit such activities.

In reality, it is often safer to do some routine tasks during operation than during an outage when there are all kinds of non-routine activities and associated temporary hazards present. Risk assessment is an ideal way to bridge the gap between workers and managers when the rules need review.

Things Workers Do to Put Themselves in Danger

Failure to Respect the Conveyor System

A belt conveyor is a highly powered machine with thousands of moving parts. These moving parts can not only severely injure a worker, but make that injury happen very fast. There is the temptation to think that 'I can move faster than the danger' or 'I have always been able to dodge that.' The reality is that the conveyor moves extremely fast.

The element of complacency also influences the workers. An unsafe practice repeated becomes an unsafe habit. The habit becomes so ingrained a worker may not even realize it is being done. Human beings have a tendency to take ownership of habits, good or bad, to the point of becoming threatened when the habit is questioned.

The reality of a belt conveyor is that it is powerful, quick, and dangerous. The conveyor does not care if 'I think I am faster'; it does not care if 'I have always done it this way and nothing has happened'; and it most certainly does not care if 'I do not think I can get hurt by a conveyor, I have been around them for a long time.' Because of the rhythmic motion of a conveyor, it can induce a hypnotic effect which results in a worker losing focus. It seems as harmless as a purring lion, when in reality it is just as unpredictable and dangerous. The reality is not a question of 'if' but 'when' an accident will occur when a worker loses respect for the power and constant changeability of a conveyor.

Forgetting these simple truths about conveyors has contributed to many injuries and fatalities.

Working Around a Moving Conveyor

Martin's calculation of data from the Mine Safety and Health Administration (MSHA) recorded between 1995 to 2011 shows there were 57 fatalities involving conveyor belts in mines in the United States. Of these fatalities, Martin estimates 66 percent happened while the belt was moving. A worker either became tangled in a moving component or was crushed by a piece of moving equipment. A vast majority of these fatalities were the result of maintenance or housekeeping being conducted on a conveyor that is fully energized and able to move. (**Figure 3.1.**)

Figure 3.1.

Working on or around an operating belt conveyor can lead to serious injuries and fatalities.

Figure 3.2.

Improper lifting presents a risk of injury for workers who need to work on or around conveyors.

Figure 3.3.

Taking a 'shortcut' by crossing under an operating belt conveyor can lead to injury.

These fatalities were caused by two compounding practices. The first was to perform maintenance without thoroughly locking, tagging, blocking, and testing the conveyor. Another unsafe practice was to touch a moving conveyor belt with a tool of some sort. When these two choices are combined, the results are usually severe and often fatal. Even working on a conveyor that is turned off, but not locked out, can lead to tragedy. What is not evident in these statistics are factors like company culture, time pressures to complete the job, the training given to the injured worker, and so on. Often these and other factors are as contributory to the accident as the unsafe act(s).

Improper Lifting

An industrial setting contains many items that can be considered lifting hazards. In the course of maintaining a conveyor, a worker may have to lift and carry such equipment. (**Figure 3.2.**) Unsafe practices include trying to lift an item heavier than a worker can handle and not using the accepted techniques for proper lifting. Failure to do either can result in injury to the worker; failing to do both increases the likelihood.

In addition, a loss of balance or fall next to a moving conveyor—induced by carrying a heavy or awkward item—only amplifies the hazard potential.

Unsafe Crossing of the Conveyor

Conveyor belts are often lengthy and bisect a production facility. (**Figure 3.3.**) Workers are often required to cross a conveyor line to get to the area that is in need of maintenance. To save time a worker is likely to step over or cross under a conveyor.

Crossing under offers multiple hazards. Return idlers may be considered guarded by location but what if the crossing path is over a pile of spillage or carryback? If the head of the worker comes in contact with the moving conveyor belt, the worker's hat will be quickly abraded resulting in a very serious head injury. If the belt catches the hat or head, the worker will be pulled toward rolling components. Crossing under also places the worker at risk from falling objects. Material from the belt's cargo or conveyor components could fall on a worker causing injury or death. More likely the spillage or carryback will cause a trip resulting in a muscle strain or worse.

Crossing over a conveyor without using a designed and designated crossover structure offers dangers as well. The conveyor structure is not designed for human climbing; it is designed for mounting and support of components and the cargo. There is a high potential for a slip and fall. If lucky, the worker may fall on the ground; if unlucky, the worker will fall onto the conveyor belt. If the conveyor is in operation, the worker will be carried downstream. This may result in contact with the conveyor structure and rolling components or being thrown off the conveyor at the discharge. Traveling on a conveyor with the material will most likely result in injury. Falls from heights frequently result in permanent disability or death.

Loose Clothing and Other Improper Attire

The clothes worn can place a worker in danger. (**Figure 3.4.**)

There are certain types of clothes that should be avoided around conveyor belts. Many choices are eliminated by proper personal protective equipment (PPE), but others are not covered by PPE.

- **Open-Toed Shoes** – An industrial environment offers many hazards to the feet of workers. Items on the ground can pierce a foot. Heavy items can fall on the foot of a worker. Hot items can burn exposed skin. Footwear that does not completely protect the worker will create a danger.
- **Shorts** – Even though in some companies or countries short pants are allowed, shorts leave large sections of the worker's legs exposed. Hot items could burn flesh. Moving components could abrade flesh. If the shorts are baggy, they could become entangled in moving conveyor components. Pants should not be manufactured from a material that is flammable or not self-extinguishing.
- **Loose Shirts** – Shirts with items hanging out can become entangled in conveyor components. Shirts should be made from a fire-retardant fabric.
- **Hooded Sweatshirts** – The drawstring on the hood or the hood itself can become entangled in equipment. The hooded sweatshirt itself may be flammable.
- **Low-Visibility Clothing** – The clothing of a worker may be dark in color or blend in with the surrounding environment. This will result in a reduction of visibility to heavy-equipment operators. If they cannot see a worker, that worker is in danger.
- **Sunglasses or Prescription Glasses** – Any number of flying objects can destroy a worker's eyesight if the worker is struck

Figure 3.4.

Improper attire is a poor safety practice for any type of industrial operation.

1

in the eye. Prescription glasses and sunglasses should have the shatterproof properties of safety glasses. Without side shields, these glasses do not provide the protection from flying debris that safety glasses with side shields do.

Glasses and sunglasses sometimes have lanyards. These lanyards present a hazard if they become entangled in moving conveyor equipment.

- **Hats and Caps** – A soft fabric head covering will not protect a worker from falling or flying objects. Some hats have lanyards that can pose entanglement hazards.
- **Lanyards** – Identification badges are often clipped to a worker or hung with a lanyard around the neck. These lanyards can become tangled like any other loose item. If the lanyard does not break away, the worker may be drawn into the moving components of a conveyor system. Lanyards should be of the breakaway type.
- **Rings and Other Jewelry** – While fashionable, jewelry can be an often overlooked danger to a worker or the process.

  If a ring is caught by a rotating tool or moving conveyor component, it can pull off an entire digit or draw the worker into the machine. Earrings and necklaces offer similar hazards. In the unlikely event that the ring is ferrous, it will be attracted to strong magnets and can heat up causing burns.

Figure 3.5.

Long, unconfined hair around the moving parts of operating conveyors poses a risk of injury.

Workarounds and Shortcuts

An intelligent and creative worker will invent ways to speed up or make work easier. Some of these shortcuts bypass the safety hardware and proper work procedures, thus putting the worker in harm's way.

The most common of these workarounds involves the improper locking out of a conveyor system. The purpose of a lockout is to de-energize all sources of energy whether latent or active. Failure to properly lockout can exist in many forms—varying from disregarding lockout requirements, to working on a moving conveyor, to improperly stopping the conveyor. An example of this procedure would be pulling the emergency-stop cord and assuming the conveyor is de-energized.

Another common workaround involves entering a confined space without following established procedures. A confined spaced is any enclosure that is large enough and configured so that an employee can enter and perform assigned work, has limited or restricted means for entry or exit, and is not designed for continuous employee occupancy. Very specific rules apply to the worker when dealing with confined space. Failure to follow those rules can result in increased danger or death to the worker. Common mistakes around confined spaces include:

- Entering a confined space alone.
- Not checking gas levels in a confined space.
- Failure to ensure other systems in the confined space are de-energized.

Loose Hair

Between changes in fashion and the presence of more women in the workplace, long hair has been an increasing trend among workers. (**Figure 3.5.**) While there is nothing wrong with long hair, loose long hair around conveyor components is a risk.

If hair becomes entangled in a moving part, it will be pulled toward the moving component. A standard shaft rotates at 3,600 revolutions per minute. If that shaft is 75 millimeters [≈3 in.] in diameter, its surface moves at 28.27 meters per second [≈94.25 ft/s]. If a 450 millimeter [≈18 in.] length of hair were to become entangled, it would entirely wrap around the shaft in only 0.03 seconds.

The best case would be for the hair to break, and the worker would suffer a mild discomfort. A worse case would involve multiple lengths of hair being grabbed and so the scalp fails before the hair. The absolute worst case would be both the hair and the scalp not failing, and the worker's head being pulled into the rotating shaft.

Riding the Conveyor

Rather than walking, a worker may be tempted to ride the conveyor to be transported to other parts of the plant quickly. this practice is called man-riding. (**Figure 3.6.**)

This transportation is without the benefits of restraints or even seats. The worker has no control of speed and has no ability to stop the conveyor in the event of danger.

The worker may also strike any stationary obstruction in the conveyor's path.

The problem of exiting the conveyor must also be considered. A jump from a moving conveyor may result in fall injuries. Momentum states that when the person jumps from the conveyor, that person will land and keep moving in the direction of the conveyor movement at approximately the same speed.

There are regions of the world—including Germany, South Africa, and the United Kingdom—where some facilities use 'man-riding conveyors' as the appropriate method for workers to reach their work stations. In the interest of safety, these facilities should have specially designed conveyors or at least special boarding and disembarking stations. In addition, special training should be provided to teach workers how to board, ride, and disembark in a safe manner. (**See Chapter 22 Man-Riding Conveyors**.)

In any location, even with special training, belt-speed restrictions, and other special safety features, riding a conveyor is a risky and dangerous practice. Allowing man-riding seems a relic of an era with a great deal less concern with worker safety. It should be prohibited.

Obstructions

Anything that is in a worker's line of travel is an obstruction. (**Figure 3.7.**) These can range from piles of spillage, items lying on the walkway or work areas, as well as low overheads. An obstruction can cause several hazards. It can present the opportunity for a trip and fall. If the obstruction is in the middle of the

Figure 3.6.

Riding a conveyor can be hazardous even in those locations where man-riding is an accepted practice.

Figure 3.7.

Obstructions, such as discarded components or tools left in the conveyor's vicinity, can create a risk for a slip, trip, or fall accident.

walkway, a worker will have to go around it. If a worker chooses to maneuver closer to a conveyor, this decision places the worker closer to the hazards of the conveyor. An obstruction will offer the same hazards every time it is encountered. An unremoved obstruction is just as hazardous as a newly discovered one.

Drowsiness

An industry 'rule of thumb' is that an average worker has a reaction time of 0.36 seconds. If this worker becomes tangled in a conveyor belt traveling 1.5 meters per second [≈300 fpm], the worker will be carried 0.54 meters [≈21 in.] before even realizing what has happened. As previously stated, this is a danger in and of itself.

Martin calculations from a study, conclude that moderate sleep deprivation of only 22 hours can slow reaction times by 9.3 percent. Sleep deprivation makes an already dangerous situation even worse.

Substance Abuse

The research on drowsiness establishes that drowsiness from being awake 22 hours can slow reaction time by 9.3 percent. This is almost identical to the reaction time for a person with a 0.05 percent blood alcohol content. Increasing the blood alcohol level to 0.1 percent slows the reaction time by 16 percent versus a sober, awake worker. On a belt traveling 1.5 meters per second [≈300 fpm], this would equate to an additional 0.08 meters [≈3 in.] of travel before the human brain can register what is happening. This is in addition to the 0.54 meters [≈21 in.] of travel from reaction time alone. This additional distance may spell the difference between minor injury, severe injury, or death.

In addition to increased reaction time, many substances—including legally prescribed medications—can impair judgement, affect balance, and even alter the perception of reality. These are all things that can be hazardous or even fatal around a conveyor belt.

Figure 3.8.

The removal of guarding—and the non-replacement of guarding after maintenance procedures are completed—can create a risk when the conveyor is restarted.

Unmarked Work Areas/Guards Removed and Not Replaced

If a worker is repairing a component of a conveyor, safety guards might be removed or some other part of the system altered. (**Figure 3.8.**) If the work area is unmarked, a passerby does not know there is a potential danger present. A person passing can be exposed to any of the dangers present without knowing about them. This could be dangerous and even fatal for the worker doing maintenance and the person walking by.

Removing any type of safety guard without authorization is also risky. Guards are designed and installed to protect the worker from an obvious hazard. If that guard is removed, the worker is exposed to an already identified hazard. The modification of safety controls defeats their purpose.

Toxic Materials Conveyed Without Due Warning

Conveyor systems are sometimes used to transport dangerous bulk materials which have hazardous components such as silica. As dangerous as these chemicals are in and of themselves, ignorance of the scope of the danger can place a worker in danger. If management knows the danger of the conveyed material, but does not take steps to communicate that to the worker in a clear and concise way, or does not properly maintain control systems, the worker can be exposed to a threat.

Broken Pull Cords and Other Neglected Safety and Control Systems

Emergency-stop pull cords are a worker's last line of defense if the belt needs to be stopped. If a worker becomes trapped or a piece of equipment will be destroyed unless the belt is stopped, pull cords allow a worker at the belt to stop the conveyor. As stated before, there is not a lot of time to react, so a worker will need a way to stop the conveyor quickly. If the cord is broken, the switch is not working, or the system is disabled, the workers have lost the one final tool they have to protect themselves. (**Figure 3.9.**)

Unfortunately, it is common practice to disconnect or bypass safety and control devices which cause nuisance stoppages of the conveyor. Most common of these bypassed controls are chute-level and wander switches. A bypassed plugged-chute sensor most likely is the result of frequent high levels of material in the chute. But, when it is not just an overfull hopper and the chute actually overflows, many hazards are possible. These hazards include belt slippage resulting in a fire, belt breakage resulting in a major outage, or large amounts of spillage.

Unusual Events Forcing Risks

A worker cannot prepare for every emergency. (**Figure 3.10.**) Unforeseen events—a crashed haul truck, a plant fire, or a severe lightning storm—may lead a worker to seek shelter near a moving conveyor belt. The larger emergency may cause the worker to forget the conveyor is still operational and dangerous. Just because something is more dangerous than the conveyor, it does not take away the danger of the conveyor.

Worker Lack of Focus / Inattention

In addition to the physical hazards of a conveyor and the common unsafe practices around conveyors, a worker can be put in danger due to lack of focus. (**Figure 3.11.**)

When a worker is focused solely on completing a task, that worker may forget about details of the specific job. Some of the first things to be discarded are safety and redundant tasks. These omissions give rise to shortcuts, and shortcuts can lead to injuries or fatalities. The very focus that allows a worker to complete the task at hand can actually be the cause of the worker's failure in regards to safety.

The current industrial environment is encouraging an output-based mentality and business model. The window of opportunity to perform basic maintenance and repairs is shrinking

Figure 3.9.

Neglected safety equipment (such as the broken cord on this pull-rope emergency-stop switch) creates a hazard.

Figure 3.10.

Unusual events occurring in or near a plant can lead to unexpected and potentially hazardous encounters with belt conveyor systems.

Figure 3.11.

In the 'real world' of plant operations, workers can be given conflicting priorities which result in a distracted performance that leads to safety incidents.

1

without workers at the facility realizing it. Very few facilities have adequate maintenance staff to devote time to anything other than major equipment repair, leaving many of the components related to safety unmaintained indefinitely. That is because output is the primary consideration, and the conveyor will run without maintenance.

Industry and workers alike are adapting to this accelerated pace by working smarter and creating ways to work faster. Industrial suppliers are also providing mechanical solutions to the diminishing time problem.

In addition to the time pressure put on maintenance, there are labor issues as well. If the workers that normally do maintenance are removed, remaining workers have to work even faster or some maintenance tasks are left unperformed.

In this environment, there is a strong temptation to cut corners to finish the job before the deadline. A worker will be judged, rewarded, or disciplined on the effectiveness of the solution and the duration of the work. To meet these goals, a worker may sacrifice safety as it will be unnoticed if nothing goes wrong.

But unfortunately, cutting corners here and there leads to unsafe habits. Unsafe habits lead to injuries and fatalities.

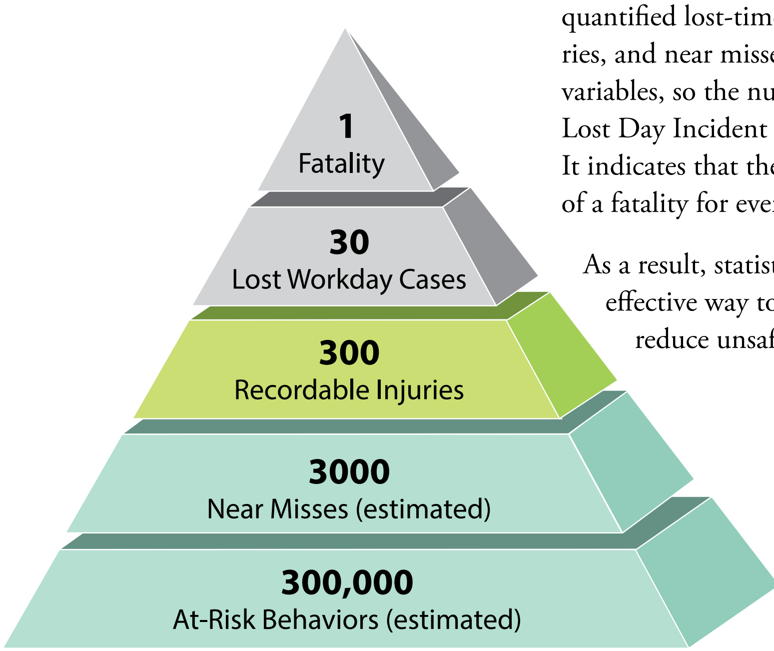


Figure 3.12.

Industry knowledge indicates that for every fatality, increasingly larger numbers of lost workday cases, injuries, near misses, and unsafe behaviors occur.

The Multiplying Effect of Unsafe Work Practices

Sometimes, an accident occurs due to a combination of several poor work practices. An MSHA *Fatalgram* recounts the story that in 1999, a fatality occurred at a mine when a worker entered an unguarded area, and then entered a confined space alone near an operating conveyor that was not locked out. The worker's clothing then became trapped in the conveyor's operating tail pulley. Four unsafe practices and two unsafe areas combined to result in a catastrophic event. Any individual factor may have led to injury or even death, but the combination certainly proved fatal. Whether the risk was multiplied, or merely showed this particular worker's lack of knowledge about proper work practices or propensity to ignore the best practices, is a moot point. Regardless, the result was a fatality.

CLOSING THOUGHTS
The Importance of Proper Work Practices

In a 2003 study, ConocoPhillips Marine found a correlation between fatalities and unsafe practices. The study showed that for every fatality there are an estimated 300,000 unsafe behaviors. (**Figure 3.12.**) The research also quantified lost-time accidents, recordable injuries, and near misses. These are independent variables, so the numbers do not mean that Lost Day Incident number 31 will be a fatality. It indicates that there is a statistical probability of a fatality for every 30 lost work days.

As a result, statistically speaking, the most effective way to reduce fatalities is to reduce unsafe behaviors.

Section 2

CONVEYOR ISSUES AND HARDWARE SOLUTIONS

2

Chapter 4 Switches and Sensors

INTRODUCTION
Sensing a Need

There are a number of switches, sensors, detectors, and alarms that can be installed with conveyors. These controls are commonly used on conveyors and are designed to either warn of an unsafe or potentially unsafe condition or serve as an emergency means to shut down the conveyor at a point close to danger zones. They are protective devices within the control circuits designed to be actuated either by the bulk material, the movement of the conveyor, or a positive action by a worker. Many of these provide the dual benefit of preserving the equipment and protecting the human element from hazards in the plant. In the context of this chapter, we discuss the equipment benefit, but our key concern is the reduction of risks for workers.

European standard *DIN EN 620 Continuous handling equipment and systems – Safety and EMC requirements for fixed belt conveyors for bulk materials* section 5.7.2.11 Automatic Malfunction Detection specifies:

> Where appropriate, the following automatic malfunction detection devices shall be installed which shall be constructed and mounted so as to minimize the risk of inadvertent operation:
>
> a) belt misalignment detection devices;
>
> b) conveyor, chute, hopper, blockage/over-load detection devices;
>
> c) shaft rotation sensing devices; [zero speed];
>
> d) belt under-speed sensing devices [belt slip];
>
> e) heat sensing devices;
>
> f) height and/or width sensing devices.

The section goes on to specify what should happen in the event of a problem, saying:

> If a hazardous condition is detected, an unambiguous acoustic and/or visual warning signal shall be provided to the conveyor operator in accordance with *EN 457:1992, EN 842:1996, EN 61310-1:1995* as appropriate, or alternatively, in extreme circumstances a stop may be automatically initiated. In particular circumstances, linked supplying conveyors may be automatically slowed - down, or stopped in a suitably controlled manner.

EN 620 5.7.2.2 Safety devices also notes the importance of matching switches to the application conditions:

> Safety devices, (e.g. trip devices, ultimate-position switches, slack-rope switches, governors, interlocking switches, emergency stop devices), shall be designed, selected, located, and/or protected to meet intended site conditions, and the various applications of the equipment.

In the now superseded Australian standard *AS 1755-2000 Conveyors – Safety requirements*, various conveyor stop-control systems are identified as mandatory or recommended. (**Figure 4.1.**)

Emergency-Stop Systems

The vast majority of bulk-materials-handling conveyors are greater in length than 2.5 meters [≈8.5 ft] and incorporate pull-cord or pull-wire switches as emergency-stop switches (E-stops) along sections of the conveyor that are accessible to people. (**See Chapter 6 Pull-Rope Emergency-Stop Switches.**)

Many regulations allow alternate means for emergency-stop protection on especially short conveyors. A short conveyor is defined as any

PROTECTIVE STOP CONTROLS		
Required	**Problem**	**Suggested**
	Bearing over-temperature	X
X	Belt slip	
X	Belt tracking	
X	Blocked chute	
	Brake over-temperature	X
X	Brake release	
	Fire detection	X
X	Fluid coupling over-temperature	

Figure 4.1.

Conveyor stop controls as required or recommended in the now obsolete Australian standard.

conveyor where the entire length of the conveyor is visible from the control station.

The preeminent standard for emergency-stop switches is *ISO 13850* but many standards require emergency stops only in general terms.

In section 6.1.2., *ASME B20.1-2015* allows:

> The use of portable emergency stop controllers in lieu of permanently installed pull cords, push button stations, etc. … for maintenance personnel who patrol overland conveyors. At those points where personnel are normally stationed, the conveyors shall be equipped with permanently installed pull cords or similar stop controllers.

2

However, the above standard provides no definition for overland conveyors.

REGULATIONS AND STANDARDS Emergency-Stop Systems

There is technology that has been approved for complex systems—often used in package handling or automated warehouses—where mechanical-latching switches can be replaced with redundant solid-state or programmable-logic circuits. In addition, the success of proximity sensors on underground mobile machinery to reduce crushing accidents is being applied to conveyor guards and hazardous areas. However, in bulk-materials handling, mechanical-latching switches are still by far the most common stop devices.

BEST PRACTICES Emergency-Stop Systems

There is such a variety of combinations of conveyors, conveyor configurations, and hazards in bulk-materials handling, it is impossible to specify that all conveyors incorporate all types of safety protection devices and controls. In consequence, the best practices are:

- All conveyors require e-stop systems.
- All conveyor designs and layouts require a risk analysis to identify which safety warning devices are appropriate.

Belt-Alignment or Wander Switches

Many conveyor belts mistrack; some 'wandering' of the belt is normal. But when the belt travels too far off the theoretical centerline of the conveyor structure, this wander leads to significant damage and safety issues.

Mistracking can cause significant damage to the edges of the belt. A damaged belt edge can catch on the conveyor structure or components and cause longitudinal ripping of the belt. Structural members can quickly be cut in two by a conveyor belt leading to a structural failure. Falling return rollers have resulted in serious accidents.

When the belt mistracks too far it can come into contact with the conveyor structure or enclosures. The belt can rub against the discharge chute and against the structure along the conveyor run. Both of these conditions can cause structure damage and lead to the generation of heat from the friction. Friction has been identified as a possible ignition source for belt fires. Both fire and structural failure can obviously cause a safety hazard and result in injury. Belt fires and structural failures have the potential to become major events leading to an enterprise- or community-wide disaster.

At the loading end, the belt can run out from under the loading skirts. Once the belt runs out from underneath the skirtboard, it usually will not return to a stable position because of the natural bow in the belt and the pressure of the sealing strips. If not corrected, this type of mistracking can result in the belt turning over on itself.

Mistracking from under the skirts can create immediate and significant spillage.

To eliminate the damage mistracking can cause, belt-wander switches are installed on the sides of the conveyor. (**Figure 4.2.**) Belt-alignment sensors are usually located at the discharge and at the loading areas of the conveyor, but can be distributed along the conveyor at intervals depending on the conveyor route. Belt-alignment or wander-control switches are typically installed on both sides of the belt at the loading and discharge ends of conveyors and at other locations along the conveyor in order to signal belt mistracking beyond acceptable limits. Note these switches will not eliminate the wander, but just shut down the system when the mistracking is so great it imperils the belt. Since a belt-wander switch is activated by the edge of the belt, a damaged edge decreases the effectiveness of the safety device.

Available switches include roller switches, limit switches, whisker switches, proximity switches, or photoelectric switches. Typical operation involves two-stage triggering of contacts by the lateral movement of the belt beyond limits determined by the conveyor design and operation. First, a set of contacts sends a warning signal of belt mistracking when the belt moves laterally more than a preset limit but with less movement than would cause belt damage, spillage, or structural damage. The warning signal does not initiate an emergency-stop condition. A second set of contacts sends an emergency-stop signal when the belt shifts beyond acceptable limits. As an emergency-stop control function, resetting the switch does not in itself restart the conveyor. The travel limits for both the warning and emergency-stop function are typically adjustable.

REGULATIONS AND STANDARDS
Belt-Alignment or Wander Switches

Australia

The recent Australian/New Zealand standard *AS/NZS 4024.3611-2015 Conveyors – Belt conveyors for bulk materials handling* offers instructions for systems to control belt wander in section 2.8.2.6. The passage notes tracking devices are required to stop any excessive lateral movement which would allow uneven loading or where the belt might contact the stationary steel structure—either of which can cause spillage, frictional heating, or damage to the belt and/or structure.

The standard identifies the following as locations for the installation of tracking devices: head, takeup and tail pulleys, and the drive head, as well as on belts loaded at a transfer not near a tail pulley. According to the standard, the devices shall be installed within 5 meters [≈16.5 ft] of locations where mistracking would affect conveyor operations, such as load and discharge chutes or critical structural steel or components. The standard then adds that in cases with the risk of movement in the structure (as in underground mines) the distance between tracking devices may need to be shorter.

The standard also specifies that the resetting of the tracking device should be done at the location where the device has been activated, unless another system (such as closed-circuit television) verifies that it is safe to resume operations.

Brazil

In *NR-22 Safety and Occupational Health in Mining,* section 22.8.3.1. notes:

> Continuous belt conveyors must have suitable devices that interrupt their operation when safety limits are reached, as specified in the project, which must include at least the following conditions: …
>
> c) abnormal belt misalignment

Brazil's standard *NR-12 Machinery and Work Equipment Safety* presents similar requirements in section 12.92.

Figure 4.2.

Positioned by the edge of the conveyor, a wander switch will shut down the system if the belt moves out of the desired path.

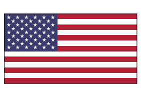
Europe

In its discussion of Automatic Malfunction Detection, European Norm *DIN EN 620* section 5.7.2.11 includes “belt misalignment devices” among the devices that shall be installed.

South Africa

South African Conveyor Manufacturers Association’s guideline *Safety Around Belt Conveyors* (CMA MS01 Rev04/2016) section 5.2 Belt Alignment states:

> When the edge of the belt trips the alignment switch for a timed period, power to the conveyor is interrupted and the system halts immediately. An adaptation of alignment sensors for large steel cord belts is the continuous measurement of edge displacement, termed ‘edge tracking.’
>
> Edge tracking in steel cable belts provides an indication of tension distribution within the carcass among the support cables. Upon installation, each steel cable belt exhibits an edge-tracking signature for a belt revolution.
>
> A deviation in the edge tracking displacement at a later time would suggest a problem in the belt cable tension distribution. However, these systems are relatively sophisticated and are usually installed only on extremely strategically sensitive conveyor systems.



United States

In United States Mine Safety and Health Administration (MSHA) and Occupational Safety and Health Administration (OSHA) regulations, the requirements for stop switches are mentioned only in general terms. American National Standards Institute/American Society of Mechanical Engineers (*ANSI/ASME) B20.1* does not mention belt alignment or wander switches specifically.

BEST PRACTICES
Belt-Alignment or Wander Switches

Misalignment or belt-wander switches incorporating a two-stage actuation—providing a first warning of belt mistracking and then emergency stop when the belt continues to mistrack—should be installed:

- On both sides of the belt as it travels into the discharge pulley.
- On both sides of the belt as it travels into the tail pulley.
- On both sides of the belt as it travels into intermediate drive pulley(s) (if used).

On reversing conveyors, misalignment switches should be installed on both sides of the belt at both terminal pulleys.

On conveyors with pulley centers less than 10 meters [≈33 ft], only one switch on each side of the conveyor is normally required.

Misalignment switches should be set to shut down the belt before material spills or the belt contacts the structure.

Maintenance personnel should test switches on a monthly basis.

Belt-Slip (Zero-Speed) Switches

If the belt slips or stops moving and the drive pulley continues to rotate, temperatures are quickly reached at the pulley/belt interface that are sufficient to cause ignition of the belt, pulley lagging, or combustible bulk materials. The combination of an unmoving belt and continued pulley rotation can also indicate a broken or stalled belt. If for some reason the tension in the belt is below the tension required to drive the belt, a loaded belt can slip backwards causing spillage. The spillage can be significant and quickly bury personnel and equipment in confined conveyor galleries.

Most regulations regarding belt slip are based on the needs of underground coal mines to prevent friction-generated fires where a belt has stopped but the drive pulley continues to rotate, or the pulley has stopped and the belt continues to travel. If a belt is rated fire retardant according to *DIN EN ISO 340*, it can only support a flame or glowing embers for up to 15 seconds. In this length of time, a relatively slow belt operating at 2.5 meters per second [≈500 fpm] will travel 37.5 meters [≈123 ft]. If the fire is not detected, the belt can burn into two pieces, potentially causing a catastrophic event in the form of a fire or out-of-control belt. Even if the belt does not ignite, its carcass strength can be seriously damaged, creating a latent hazard if the belt is put back into service.

Drum friction tests—such as *DIN EN 1554* on belting for general use or *BS EN 14973* on belting for underground use—simulate a belt slipping over a jammed pulley or a pulley rotating under a stationary conveyor belt. The purpose of the test is to measure whether the surface temperature remains under a required maximum after a specific time and under a specific tension. There are different tests for fabric and steel cord belts. (**See Chapter 15 Conveyors, Belting, and Fires.**)

To effectively determine if the belt and drive pulleys are moving at the proper speed, a combination of monitoring methods is needed. There is a wide variety of switches and sensors that can accomplish these tasks.

A common type of sensor used for pulley rotation uses magnets. These magnets are either embedded in the pulley or affixed to the structure. As the pulley rotates, the magnets are detected by a sensor and the generated pulses are proportional to shaft rotational velocity. When the pulse falls below a trip set-point threshold, a relay de-energizes and activates an alarm. Belt movement is often monitored by a wheel in contact with a clean side of the belt—the side of the belt not in contact with the bulk material—and a signal-generating device. When the belt falls below the set point, a warning signal is typically generated rather than an emergency-stop signal.

Shaft-speed sensors, pulley-speed sensors, and belt-movement sensors can detect the direction of movement or rotation.

Generally belt-motion sensors are narrow, small-diameter wheels that are spring-loaded to maintain contact with the unloaded or 'bottom cover' side of the belt whether the belt is loaded or unloaded. These wheels do present a nip-point hazard but the contact force is generally low; they are usually installed in the center of the belt so the risk of being caught in this nip point is minimal. Each situation needs to be evaluated, but in general, it is wise to guard or otherwise secure zero-speed and belt-motion switches against damage and tampering. This protection can easily incorporate personnel protection at the same time.

The arrangement of some sensors can create a hazard. Theoretically, the driven pulleys should be guarded to prevent inadvertent contact with the rotating tabs on pulleys and shafts. In reality, what is often found is a fixed, non-removable guard protecting the pulse sensor, and no fixed guard protecting workers from the rotating tabs which become rotating knives. Amputations from this arrangement have been reported.

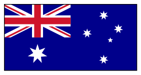
Figure 4.3 shows an unguarded zero-speed switch with the tabs welded to the pulley hub. This arrangement presents an amputation hazard and also does not necessarily allow the sensor to provide notice of hub connection or shaft failure.

Figure 4.3.

The tabs welded onto this conveyor pulley rotate past the zero-speed sensor to indicate pulley (and belt) motion. As there are no guards on the tabs, their rotation creates a safety hazard.

2

REGULATIONS AND STANDARDS
Belt-Slip (Zero-Speed) Switches

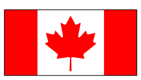


Australia

The Australian standard for stop controls for belt slip is presented in *AS/NZS 4024.3611-2015 Conveyors – Belt conveyors for bulk materials handling*. In section 2.8.2.2, the standard specifies that stop controls shall be installed between the belt and every driven pulley. The stop device will stop the conveyor if belt slip exceeds 10 percent of the conveyor's design speed for a prescribed time, which shall not exceed four seconds.

Brazil

The Brazilian regulation *NR-22 Safety and Occupational Health in Mining*, section 22.8.3.1, includes "abnormal belt slippage on pulleys" among the conditions which must have devices installed to interrupt conveyor operations "when safety limits are reached."



Canada

In the Occupational Health and Safety Act, as published in the *Revised Regulations of Ontario (R.R.O.) 1990, Regulation 854 Mines and Mining Plants*, section 196, subsection (5) specifies:

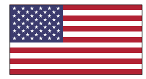
> A conveyor in an underground mine shall have,
>
> > (a) devices that guard against excessive slip between the belt and the driving pulley.

CSA Clause M421-11 (R2016) Use of electricity in mines specifies in 4.4.3.6 that:

> A belt conveyor that is either used underground or more than 15 m long [≈50 ft] and is installed in a building or other closed-in structure shall be provided with a belt-slip detection device to stop the drive motor in the event of belt blockage or slippage.

Europe

In its list of mandatory and recommended safety devices, European standard *EN 620* specifies belt-slip switches as mandatory in underground coal mines and other hazardous locations and as recommended on surface conveyors.



United States

MSHA regulations in *30 CFR 56/57.4503* state:

> Surface belt conveyors within confined areas where evacuation would be restricted in the event of a fire resulting from belt-slippage shall be equipped with a detection system capable of automatically stopping the drive pulley.

BEST PRACTICES
Belt-Slip (Zero-Speed) Switches

- Install rotation sensors on all main pulleys and bend pulleys.
- Do not allow rotation-sensor pulse generators to create a hazard.
- Install at least one belt-motion sensor on each belt.
- Set the device to send an emergency-stop command without time delay when the rotation speed or belt speed is more than ± 10 percent of design speed or control set-point speed range.
- Protect the rotation and belt-motion devices against damage or failure from fugitive bulk materials and tampering.
- Protect personnel from nip and shear points created by the installation of rotation and motion sensors.
- Test the rotation sensors monthly and keep a record of the test. Immediately repair or replace non-functioning devices.

Bin-Level and Plugged-Chute Detectors

As conveyor speeds climb higher and higher, the potential for a plugged chute causing a major incident increases dramatically. A typical high-speed—that is, more than 5 meters per second [≈1,000 fpm]—conveyor takes from 10 to 30 seconds to stop. With conveyor capacities in the 3,000 tons per hour [≈2,700 mtph] and up range, this means 4 to 12 tons of bulk material must be accommodated as surge material in the system for each conveyor in the shutdown sequence. Due to space and cost constraints, few bins are designed to handle these material volumes under emergency-stop conditions.

When a hopper outlet becomes blocked and bulk material continues to stream in, the conveyor acts like a pump where the pressure is limited only by the overload of the main drive motor. Thus bins can be force-filled and then overflow. This potentially damages the hopper, the belt, any accessory equipment, and threatens injury to any worker in the path of overflowing material.

Blocked hoppers and chutes are often beat upon using a hammer in an attempt to create flow. Every time a hopper wall is deformed with 'hammer rash,' the effective angle of the hopper is reduced in that area creating a potential starting point for a faster buildup of material in the hopper. More frequent plugging is likely in the future. Excessive hammering can damage the hopper to the point welded seams separate, creating conditions for a potential structural failure.

A typical situation is shown in **Figure 4.4**. This discharge hopper has obviously overfilled—the rocks on top of the head chute indicate material overflowing the chute—and it can be assumed the chute was only cleared sufficiently to resume production. The work platform is most likely overloaded well beyond the typical platform design load capacity of 1 to 1.5 tons per square meter [≈100 to 150 lb/ft^2].

Collapse of this platform is a potential hazard to workers on or below the platform. The large lumps seen here could fall from the normal vibration of the machine causing a falling material hazard.

Often chutes must be manually cleaned to restore operation. This often requires confined space procedures. Many fatal accidents have occurred cleaning the inside of chutes, dislodging large pieces or breaking loose substantial quantities of bulk material that can fall on workers.

In the attempt to forestall these problems, many chutes have a bin-level sensor acting as a plugged-chute detector. When the chute fills to a specified level, the sensor reacts, shutting down the conveyor to stop the flow of material so the chute can be emptied, either of its own accord or by manual cleaning.

Level measurements in bulk-materials handling can be divided into two types, continuous measurement and point measurement. Continuous-level measurement is commonly used for larger hoppers or silos to provide an indication of the level of material in storage for inventory or process control. Point-measurement devices provide a signal when the level of material in the discharge chute reaches a preset level. Point-measurement sensors are the type generally used for conveyor transfer chutes or in a sequence of conveyors with intermediate processes or surge storage requirements.

Common technologies used in chute-level detection for conveyor systems are rotary paddle, tilt switch, radio frequency, pressure pads, nuclear, and vibrating element devices. The

Figure 4.4.

A plugged-chute detector could have prevented the spillage which occurred when the conveyor remained in operation despite a blockage in the discharge chute.

2

selection of the type of level sensor is affected by different factors including the properties of the bulk material and process needs.

As a safety control, these switches are used to detect an impending chute overfilling condition indicating a probable plugged chute. As with belt-wander detectors, bin-level detectors can have more than one set point providing a warning and then an emergency-stop signal.

Level-measurement devices can also be used to indicate feeding onto the belt or into a hopper to prevent an 'out-of-stock' condition such as when the lack of material above a crusher or furnace could create a safety, dust, or process problem.

Bin-level devices are notorious for causing false trips and unnecessarily shutting down the conveyor. As a result, these devices are often overruled or even disconnected.

Part of the difficulty is in selecting a device that will work in the wide range of properties of the bulk materials being handled. It is normal for a bulk material to be in a dry, free-flowing state. However, when a property such as the moisture content or particle size-range changes, the material will cease to flow as expected—and designed for—through a conveyor discharge chute. This causes a plugged chute or blocked discharge.

If the design of the bin itself does not lend itself to a suitable protected location for the device, plugged chutes may also occur.

REGULATIONS AND STANDARDS

Bin-Level and Plugged-Chute Detectors

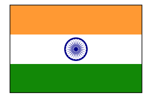
With few exceptions, the existing regulations do not require a bin- or hopper-level detector as a safety-control device but make it optional based on operating need or hazard analysis.

Australia

Section 2.8.2.9 of Australian/New Zealand standard *AS/NZS 4024.3611* requires the incorporation of blocked-chute detectors in belt conveyors handling bulk materials.

Europe

In its listing of automatic malfunction detection devices which shall be installed, European standard *EN 620* Section 5.7.2.11 includes "conveyor, chute, hopper, blockage / overload detection devices."



India

Indian standard *IS 11592* section 8.14.2.4, Special loads, states:

> These comprise the loads which shall not occur during and outside the operation of the equipment but the occurrence of which is not to be excluded. The main components of special loads are:
>
> a) Clogging of chutes — The weight of the clogging is to be calculated using a load which is equivalent to the capacity of the chute in question, with due reference to the slope angle. The material normally within the chute may be deducted. The actual bulk weight must be taken for calculation.

BEST PRACTICES

Bin-Level and Plugged-Chute Detectors

- Install level-detection device(s) on every active discharge chute and/or active hopper in the system with a two-stage actuation for first warning of bin level above 50 percent of design level and then emergency stop when the level equals 100 percent of design level for normal operation.
- Install flow-aid devices (for example, air cannon or vibrator) to support hopper evacuation and material movement when bin buildup or blockage is anticipated.
- Design sufficient surge capacity into the system to allow a controlled stop without filling the bin above the 100 percent operating level.
- Test level-detection devices monthly and record the results. Immediately repair or replace non-functioning devices.

High Wind Warnings

High winds can cause instability in conveyor structures, particularly with movable conveyors such as stackers, reclaimers, and shiploaders. These mobile conveyors and related structures are typically run on rails; with the standard rail gauges in use, it is difficult to assure stability in high winds. When these machines fail or are pushed off their tracks by high winds, significant property damage can occur with the potential for serious or fatal injuries to workers and operators.

In cases such as overland conveyors, high winds can create excessive dust or spillage. Empty conveyors are prone to being blown off their idlers in high winds.

A wind-speed sensor is commonly used to measure wind speeds on such conveyors. Typically, high winds are considered constant wind speeds or momentary gusts in excess of 72 kilometers per hour [≈45 mph]. When the wind speed exceeds the allowable design loads, an over-limit signal is sent and the machine is shut down in a controlled manner, avoiding an emergency stop.

BEST PRACTICES
High Wind Warnings

The application of specialized standards involves the details of the machine, and it is therefore difficult to make blanket statements about best practices.

- In the risk-assessment stage of the project, identify the hazards that may be related to high wind speeds.
- When it is anticipated that high winds can create a hazardous situation, install wind-speed indicators where reaching a preset maximum wind speed will send control signals.
- When wind-speed devices are used, test monthly and record the results. Immediately repair or replace non-functioning devices.

Heat Sensors and Fire Detection

Conveyor belt fires and explosions have the potential for fatal accidents and can be enterprise-wide disasters.

Safety from Lightning

Similar to the need to protect conveyors and workers from high winds is the need to reduce risk from lightning strikes.

Conveyors—as they are large metal structures (and often elevated) that are exposed to the outside atmosphere—are prone to being struck by lightning and require protection from damage and to protect all operating and maintenance staff. Even underground conveyors can be affected by lightning, as they are often supplied with electricity through cables running down the shaft or through boreholes from the surface.

As such, conveyors represent a powerful attraction for lightning strikes and should have precautions to protect both workers and equipment from these massive discharges of electrical current.

While the 2016 edition of *Safety Around Belt Conveyors* from South Africa's Conveyor Manufacturers Association has eliminated these passages, the 2013 edition offered the following in section 4.11 Lightning Protection:

> Earthing and other applicable protection standards need to be installed and adhered to. The conveyor belt protection system shall be electrically isolated from the control system and all other control networks in accordance with the requirements of *SANS 10313* or *BS 6651*. Any equipment or devices that are required to be directly connected to the control system shall be earthed to an acceptable minimum standard.

Both standards cited in the passage from the CMA guideline have now been updated. *SANS 10313* has been supplemented by the *IEC 62305 Protection against lightning* series. The standard *BS 6651* has been replaced by the *BS EN 62305* series.

It is good practice to monitor climatic conditions within the geographic area so conveyor systems can be shut down in the event lightning danger levels reach predetermined limits.

In general, the ground connections and continuity should be tested annually, and the test results recorded. Correct any grounding issues immediately.

There are a number of ignition sources which can result in fires involving conveyors; these include hot bulk materials, spontaneous combustion (self-heating) of the bulk material, frictional heating from conveyor belt slippage or failing bearings, and sparks from tramp metals in process equipment such as crushers.

Conveyors are used in processes in which intermittent steps produce high temperatures such as cement clinker and coke. The processes are designed to limit the product temperature on the belt to below the belt rating, usually by incorporating some type of cooler or dousing the material with water. Typically, high-temperature belts can handle 200° Celsius [≈400°F] bulk materials. If glowing lumps or the whole batch is over-temperature, even a fire-resistant belt can be burned through.

The dust of many bulk materials such as sugar, coal, and grain can cause explosions under certain conditions. Unfortunately, conveyor systems lend themselves to creating these conditions. Conveyor systems provide the five explosion requirements through the presence of an ignition source (heat or spark), fuel (an explosive concentration of dust), oxygen (ambient air), confinement, and dispersion. (**See Chapter 17 Conveyor Dust.**)

'Hot work'—maintenance procedures such as cutting and welding—can cause fires when the heated materials come in contact with the belt or a combustible bulk material. Often hot slag from these operations can fall into hard-to-detect locations and smolder for periods before producing a visible glow, flame, or detectable level of heat.

A well-engineered fire-detection system must address all potential ignition sources. Heat sensors are used in a protective mode to detect pending failure of components such as bearings, motors, and gearboxes. Heat sensors are also used to detect conveyor belt fires. (**See Chapter 15 Conveyors, Belting, and Fires.**) A European Commission report on belt conveyor fire detection titled *Early detection and fighting of fires in belt conveyors (Edaffic)* identifies the following components which should be monitored by heat-point detectors:

(i) tail pulleys,
(ii) head pulleys,
(iii) bend and take-up pulleys,
(iv) transfer points,
(v) loading and discharge points and
(vi) hydraulic and electrical devices.

There are two categories of heat-detection sensors commonly used on conveyors: fixed-temperature and rate-of-rise. Fixed-temperature systems are designed to operate when the air around the sensor reaches a set-point temperature, typically 57°C [≈135°F] or more. Rate-of-rise systems monitor the rate of temperature increase per unit time, typically an increase of 5°C to 8°C [≈10°F to 15°F] per minute. In general, both types of systems are used in confined areas where a rapidly growing fire is expected and where detection speed is not considered relevant.

There are several technologies used in heat sensors. Spot-heat sensors use either infrared or ultraviolet light detection. Typically, spot-detection systems are placed above the conveyor with line-of-sight detection coverage and respond to changes in the light spectrum emitted by the heated or burning material. Point-detection systems can be wired or wireless. These sensors are often integrated with a device to remove the hot spots either by mechanical rejection or spot application of water.

Linear heat-detecting systems based on fiber optics are placed along the conveyors in close proximity to the potential heat sources, primarily main pulley and idler bearings. Heat affects the fiber optics transmission capacity and allows the accurate detection of the temperature and heat source(s) along the conveyor.

Sprinklers are a detection and extinguishing system combined into one device. Typically, the sprinkler nozzle is closed with a disk or valve kept in place by a fusible metal alloy or heat-sensitive bulb rated for a specific temperature, typically 57°C [≈135°F]. As with heat detectors, the fire raises the ambient air temperature causing the alloy to melt—or bulb to shatter—thereby releasing water on to the conveyor belt. Sprinkler systems for conveyors are typically of the deluge style which flood the conveyor belt and cargo when activated. However, other types of fire suppression can be used, such as foam and dry powder.

Heat-detection sensors can be integrated into the control system as warning and/or emergency-stop devices. Detection of moving fires on conveyors can be difficult. Once the conveyor belt or cargo catches fire, the conveyor must be shut down and the damage isolated or the complete conveyor system, surrounding equipment, and building can be destroyed. Even though spot-heat sensors can be used for the early detection of fire, experience has shown that other types of sensors, such as carbon monoxide and smoke detectors, could provide better results.

REGULATIONS AND STANDARDS

Heat Sensors and Fire Detection

Australia

Where a conveyor's operation can create a fire hazard, that conveyor should be designed to minimize the potential for, detect, and finally suppress a fire as explicitly noted in *AS/NZS 4024.3610: Conveyors – General requirements*.

For information on mining applications, the *AS/NZS 4024.3610* standard refers to *Mine Design Guideline (MDG) 1032 Guideline for the prevention, early detection, and suppression of fires in coal mines*, as issued in 2010 by the Mine Safety Operations branch of the Department of Industry & Investment, New South Wales.

The belt conveyors bulk-materials-handling standard *AS/NZS 4024.3611* also provides fire detection requirements in section 2.8.2.7. Here it notes that fire detection systems shall be installed at belt conveyor drives and other areas at risk for fire. The devices shall provide an alarm as an alert to the risk of fire.

In its table listing Protective Stop Controls for Bulk Material Handling Belt Conveyors, *AS/NZS 4024.3611* shows fire-detection protective stop controls as mandatory in underground coal mines, but only as recommended in other conveyor applications.

Europe

In section 5.7.2.11, European Norm *EN 620* 5.7.2.11 includes "heat sensing devices" among the automatic malfunction detection devices which shall be installed.

United States

MSHA *30 C.F.R.* Subpart L Fire Protection, sections 75.1100 through .1103 offers detailed requirements for heat and fire detection technologies and firefighting systems.

BEST PRACTICES

Heat Sensors and Fire Detection

- Install point-detection heat sensors on main bearings of tail pulleys, head pulleys, bend and takeup pulleys, as well as on gearboxes, brakes, hydraulic, and electrical devices.
- Install linear heat detections on or near conveyor idler bearings.
- Install carbon monoxide detectors on loading points and discharge points when the bulk material is combustible.

Other Sensors

Other electronic-sensing systems have applications in improving conveyor safety or reducing the amount or urgency of maintenance, which in many ways is the same as improving safety. These sensors include:

- *Capacitance/Proximity Sensors*
  Capacitance sensors are used to detect the presence of a worker in a danger zone. These sensors are becoming standard equipment used to reduce the risk of crushing of workers around mobile equipment. In the United States, the National Institute of Occupational Safety and

Health (NIOSH) has also recommended using this technology with area guarding to reduce the chance of a worker being inside a danger zone when the conveyor starts up.

- *Vibration Sensors*
  Vibration sensors are commonly used on main bearings and critical pieces of equipment like reducers to provide a proactive indication of pending failure. Failure of

Proximity Warning Systems

Proximity Warning Systems have now become common and even required for mobile machinery in underground mining. The success of these systems has led to the consideration of additional uses, including applications in conveyor safety.

Technologies

No single technology can adapt to all conditions and circumstances. For conveyor belt safety there are two proximity warning technologies that might be used as e-stop triggering devices: capacitance and radio frequency.

Capacitance sensors detect changes in the capacitance—the electricity storage capacity—of the surrounding area. The range of capacitance sensors is affected by the environment around a conveyor, so generally a person must be within one meter [≈40 in.] of the sensor to generate a signal. Capacitance-based devices can be used in an interlock on a guard panel, as a worker would need to be close to the guard to open or remove it.

Radio frequency technology is more flexible in its application to conveyor safety. Radio frequency identification (RFID) systems can sense a unique, remotely-readable identification number and other data with wireless radio technology. A typical RFID safety system uses three components: a tag or transponder, a reader, and a controller. When a worker wearing an RFID tag comes within range, the signal activates the RFID tag, which sends a faint radio signal, and so the worker is 'sensed' to be within the controlled area.

These devices have been adapted to mining in a number of ways, including vehicle tracking, personnel tracking, and inventory control.

RFID tags can be personalized to prevent unauthorized entry to an area guard or even to track a specific worker's location. One drawback is that the worker must wear an RFID tag. The tags are often embedded in a piece of personal protective equipment (PPE)—such as a safety vest—which the worker would wear without fail.

Factors critical to the success of proximity detection systems include: they must stop the hazardous motion quickly; they must be accurate over short distances; and they must work with multiple workers and machines, in tough industrial conditions and in high 'electrical noise' environments.

Application as Conveyor Interlock

Interlocks on potentially hazardous equipment are designed to shut down the machinery if access is needed or a worker breaches the safety barrier. Thus interlocks seem a useful application for proximity sensors.

Perhaps the first application of this technology to conveyors will be in mines, where workers will already be wearing RFID proximity tags—what the Mine Safety and Health Adminstration (MSHA) has termed the "Miner Wearable Components." It seems obvious to install RFID sensors on conveyor systems at nip points such as transfer points so that the presence of a worker violating the safety zone will shut down the system.

The National Institute of Occupational Safety and Health N IOSH has suggested the development of dual level of protections systems, where there is a lock or interlock on an access gate, as well as a proximity sensor to detect if personnel are within the perimeter of the area guard.

A worker uses the RFID tag on his ID card to gain access to a conveyor.

A gate to a conveyor walkway is controlled with an RFID sensor.

bearings have been documented to cause fires and can result in catastrophic failures of shafts, pulleys, and reducers with significant safety consequences.

- *Dust Sensors*
  Dust sensors are frequently installed at transfers where excessive dust levels represent a health or explosion hazard. (**See Chapter 17 Conveyor Dust.**)
- *Gas Sensors*
  Gas sensors are installed to detect toxic or explosive gases, such as methane, carbon monoxide, and excessive oxygen levels. A common application is underground coal mining; these sensors are used in other applications where the accumulation of dangerous gas levels represent a health and safety hazard.

CLOSING THOUGHTS

In addition, many conveyors are equipped with devices to detect tramp metal and foreign materials, to detect belt rips, to monitor splice integrity, or to measure the loaded weight of the conveyor. While these systems may seem to have no overt connection to worker safety, they all serve to assure the conveyor system remains productive and on-stream, thus reducing the need for workers to attend to the conveyor and perform maintenance activities which so often put workers in harm's way.

2

2

Chapter 5

Start-Up Alarms

INTRODUCTION

Safety at the Start

Typically, conveyors have long lengths of belting and structure with numerous pulleys, idlers, and other stationary and moving components that are out of an operator's view.

Accordingly, conveyor operators must follow specific procedures to ensure the conveyor is clear of all foreign objects and people before starting. However, there are still risks that an operator will not see workers or objects on or near the conveyor. These workers will be put in peril by a movement of that conveyor.

The consequences can be grave if a conveyor—which has not been locked out—is powered up and begins to move when workers are in the vicinity and working near or on the conveyor. Therefore, many jurisdictions require that a warning be given. However, the specifics of this warning—type and duration of sound, the use of lights, length of time from warning to actual conveyor start—are not usually specified.

Safety requires that no conveyor be started unless the person starting it is certain that all persons are clear. To ensure this, the standards require a positive audible or visible warning system to accommodate different mining and milling conditions.

Lockout is Always Critical

In 2012, the United States Mine Safety and Health Administration (MSHA) issued an alert regarding best practices in lockout of belt conveyors. According to the *MSHA Hazard Alert – Conveyor Startup Fatalities*, three miners in different operations had died over the course of 20 months when the belt conveyor each was working on started unexpectedly.

The *MSHA Hazard Alert* states, "In each case the conveyor drive motor was not de-energized, locked, and tagged. In one accident, a co-worker knew the victim had not locked out."

To improve conveyor safety, the *MSHA Hazard Alert* listed the following as the best practices to avoid conveyor start-up fatalities:

- Deenergize, lock, and tag drive motor
- Establish and follow safe work procedures
- Train miners on general safety and tasks assigned
- Maintain communication with all miners
- Visually check conveyors before start-up
- Account for all miners on a work team
- Provide a prestart-up alarm
  - Loud enough to be heard
- Sound the alarm before conveyor start-up
- Use fall protection when a fall hazard exists
- Provide and maintain a safe means of access to all working places

Despite the emphasis on—and stated requirements for—lockout / tagout, it is reasonable to presume there will still be workers who are

Gravel Pit Worker Dies While Cleaning Off a Stalled Conveyor

A 41-year-old worker for a gravel company was killed while he was cleaning material off a transfer conveyor belt. The worker had been cleaning material away from the sides of a stalled and shutdown 30 inch [≈762 mm] wide conveyor.

When the foreman went to restart the conveyor, the worker noticed the conveyor's discharge chute was clogged. Although instructed to stand clear, the worker instinctively climbed on the belt to clear the chute. The foreman could not see the conveyor belt from the electric panel located near the rock washing station that was on the other side of an elevated road over the conveyor system. As a result, the foreman turned the break switch on; there was no start-up alarm system in place.

When the conveyor began to move, the workman fell onto the moving belt. He rode the belt for 30 seconds—covering the entire 225 foot [≈69 m] length of the conveyor—before being pinned under an angle iron motor brace which resulted in fatal injuries.

As a result of this accident, the conveyor controls have been relocated. Restarting of these belts will now be done while standing next to the belts within line of sight. In addition, all belts in this conveyor run—from the gravel pit to the rock washer—are interlocked on the same switch. The stopping of one will stop them all, preventing material overloading. This will ensure that circumstances that led to this fatality will not be repeated at this location.

Also, safety alarms have now been installed for restarting the belts. A 20-second loud alarm sounds before the belts will start and is followed by a 30-second delay before the belt actually begins to move.

The National Institute of Occupational Safety and Health (NIOSH) *Fatality Assessment and Control Evaluation (FACE) Report's* first recommendation includes:

> … Starting should also include a warning alarm … The addition of warning alarms and time delays is an additional safeguard that is required to protect employees working on conveyor belts or moving machinery.

working on or around conveyors that are shut down but not locked out.

The Need for Warning Signals

Today, it is generally accepted that notice should be given of impending start-up of equipment. Most moving equipment has some form of audible/visible alarm. There can be too many places where the machine is in motion, and the operator cannot see if it is clear. (**Figure 5.1.**)

Many conveyors are part of a sequence of conveyors and other process equipment that either start automatically or are started manually but remotely. This introduces a risk that the conveyor starts without warning to workers in the immediate vicinity of the conveyor. Hazards can be related to the movement of the conveyor or the creation of an atmosphere in an enclosed area that require workers to exit the area or wear protective gear to protect against harmful dust, flying materials, or elevated temperatures. The risks associated with start-up warnings are linked to the operation of the warning device, the ability to see or hear the warning, and adequate time to distance one's self from the conveyor or conveyor enclosure.

Start-up warnings can be audible, visual, or both depending upon the levels of noise, lighting, or dust, and the complexity of the conveyor runs.

The seventh edition of the book *Belt Conveyors for Bulk Materials*, published in 2014 by the Conveyor Equipment Manufacturers Association (CEMA), simply notes:

> All unguarded conveyors should be equipped with an audible or visual system that provides a pre-start warning along the entire length of the conveyor. These normally consist of horns, sirens, flashing lights, or strobes. These are activated for a period after a start is requested but before initiating motion of the conveyor.

CEMA has actually increased the strength of its published recommendation over the course of nine years. "**Some** unguarded conveyors are … ," as presented in the Fifth Edition pub-

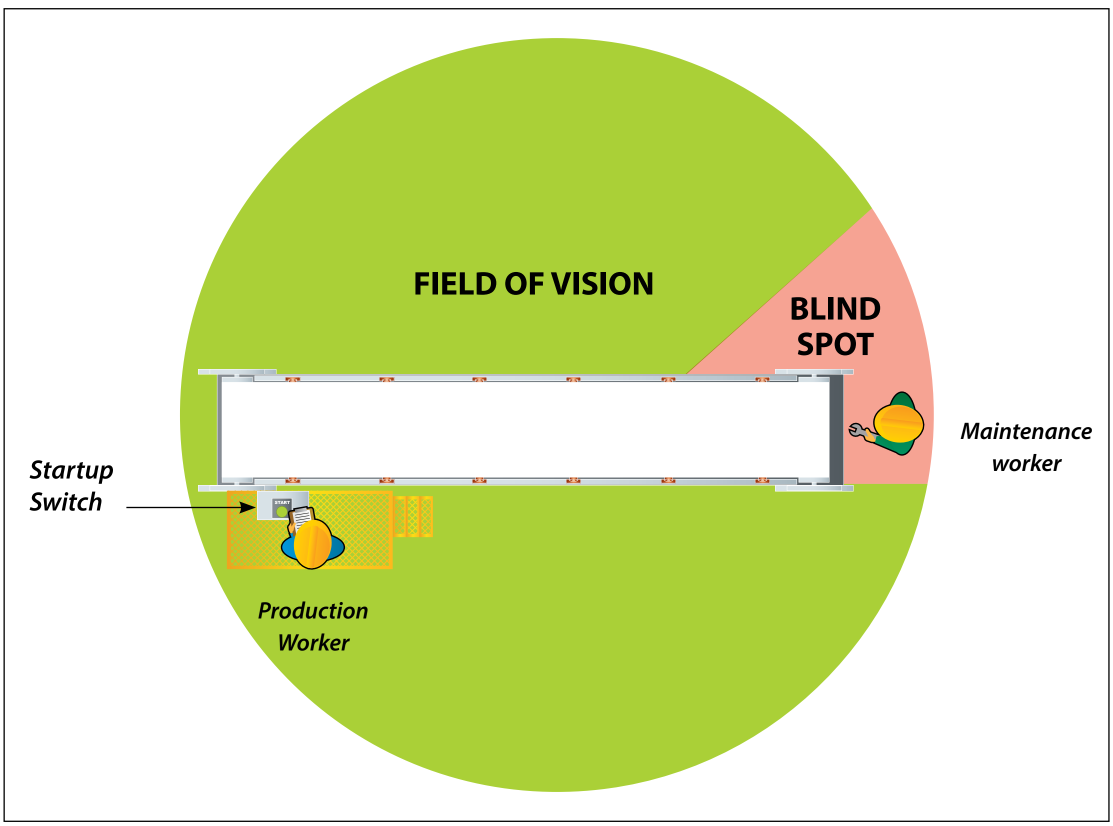


Figure 5.1.

Alarms are required where obstructions, such as the conveyor system itself, prevent personnel who would start the conveyor from observing a worker in a danger zone.

2

lished in 1997, was strengthened in 2005's Sixth Edition to "**All** unguarded conveyors should be …" [Emphasis added – Ed.].

Best Practices on Conveyor Safety, published by Workplace Safety and Health, Policy and Legislation of the Government of Alberta, provides the following guidance:

> For automatic or remote control start-up conveyors as well as for conveyors where the worker(s) cannot see the entire conveyor, a visible or audible warning device shall announce the starting of the conveyor.

Despite the general acceptance of start-up alarms as appropriate or required, there are few specifications as to the nature of those indicators. It is impossible to judge whether the lack of specifics is due to the various natures of conveyor systems and general industrial environments, or some other lack of information or interest on the part of the regulators.

The prestart warning is simply to let anyone in the proximity of potentially moving equipment know that the equipment is about to start. If a worker is not the one pushing the start button, the individual does not know when it is about to start. If there is no warning provided, there is a chance someone will be at risk when the belt starts moving.

REGULATIONS AND STANDARDS

Most jurisdictions provide regulations covering the start-up of conveyors; these regulations provide varying degrees of specificity over the nature of the warnings.

Australia

In Australia, audible warnings are required, but little guidance is given as to the specific nature of the warnings.

The Australian/New Zealand standard *AS/NZS 4024.3610* notes in clause 2.10.4 that:

Mill Operator Caught in a Conveyor Discharge Hopper and Died of Mechanical Compression Asphyxia

In its analysis of a May 1996 fatality where an operator in a wallboard and plaster plant was caught in a conveyor feed hopper, the *Maryland Division of Labor and Industry FACE Case Report* stated:

> It is unknown why the victim placed himself near the conveyor while it was operating and no one witnessed the incident. However, it appeared that the victim was attempting to adjust the belt cleaner from above the supply side of the conveyor, without locking out the power supply, when he lost his balance and fell onto the moving conveyor belt.

One possible scenario for the incident is that the victim had stopped the belt but had not locked out the power and was sitting or kneeling on the belt using a wrench to adjust the belt cleaner. The conveyor could have been started from the control room causing the victim to be pulled into the discharge chute before he had time to react.

The plant did have an established safety program and the victim had received lockout / tagout training only two months previously.

This led to the inclusion of the following as one of four recommendations in the *FACE Report*:

> Recommendation #4:
> Employers should install a start-up alarm that will sound for a predetermined time prior to starting the conveyor belt.

The discussion of this recommendation noted:

> The installation of an audible, visual or both signaling devices would give employees a warning. A predetermined warning time would ensure that workers could exit the area prior to starting the conveyor system. However, this does not replace an effective lockout / tagout procedure.

> Where an uncontrolled hazard could arise when a conveyor or conveyor system starts, an automatically operated prestart warning system shall alert people to the fact that the conveyor is commencing operation and a potential danger exists. The system shall be in the form of an appropriately timed audible warning given prior to the conveyor starting. This audible warning may be supplemented with a visual warning device. These devices shall continue to indicate until the conveyor or conveyor system has started.
>
> Where auditory or visual warnings, or both are provided, they shall not be a substitute for physical safeguards.
>
> Auditory or visual warnings shall be monitored or inspected periodically to ensure adequate levels of safety and functionality.

The clause then notes that guidance on signals and warning devices is given in *AS 4024.1202* and guidance on visual signals and auditory signals is provided in *AS 4024.1904*.

The passages below from W*estern Australia's Mines Safety and Inspection Regulations 1995* (as affirmed January 12, 2013) echo the requirements.

> 4.6 Conveyor haulage safety
>
> > (3) The manager of an underground mine must ensure that, so far as is practicable, a warning device, audible at all locations along the conveyor, is sounded each time before any conveyor belt at the mine is started to warn persons that the conveyor belt is about to start.
> >
> > (4) The manager of an underground mine must ensure that if any conveyor haulage at the mine is designed to start by remote or automatic control, the design includes an alarm, audible at all locations along the conveyor, which sounds for an appropriate period before the conveyor belt starts.

The document allows a variance in section 5.

> (5) Subregulation (3) does not apply to short conveyor haulages at shaft load stations or transfer points if signs warning of automatic or remote (as the case may be) start operation are prominently displayed at each entry to, and in the vicinity of, the conveyor system.

One thing the *Mines Safety and Inspection Regulations 1995* does specify in 17.1 General penalty is the fine for violations of this regulation (and other regulations in the document). It spells out the fines (in Australian dollars) for various categories of offenders, with fines of $5,000 (AUD) for the act of an employee as a first offense, or $50,000 (AUD) for a corporation's first offense.

Brazil

The Brazilian conveyor standard *NR-22 Safety and Occupational Health in Mining* (as updated in 2011) offers the following:

> 22.8.6 – Starting a belt conveyor can only take place 20 seconds after an audible alarm or equivalent means of communication indicating its imminent activation.

The requirements for an audible alarm are similarly noted in the *NR-22* standard guidelines for machinery:

> 22.11.4 – Machines and automatic control systems, once turned off, can only be restarted after activation of an audible alarm.
>
> 22.11.5 – Large machinery and equipment, must be equipped with an audible alarm system that indicates the start of their operation and when the direction of motion is reversed.

Canada

The Occupational Health and Safety Code 2009 from the Province of Alberta, in Part 25, subsection 365, specifies:

> 365(1) – An employer must ensure that an alarm system is installed if:
>
> (a) a machine operator does not have a clear view of the machine or parts of it from the control panel or operator's station, and
>
> (b) moving machine parts may endanger workers.
>
> 365(2) – The alarm system must effectively warn workers that the machine is about to start.

Alberta's *OHS Safety Code's Explanation Guide* 2009 offers the following:

> Part 25 Subsection 365(1)
>
> This subsection addresses the use of alarm systems when starting machinery. The start-up of machinery can cause injury to workers near the machine if they are not aware that the machine is being started and the machine is not appropriately guarded. If a machine operator cannot see the machine or parts of the machine being operated from the control panel or operator's station, and moving machine parts may endanger workers, an alarm system must be installed. The alarm system may include sirens, buzzers, horns, flashing lights or a combination of these alarms. A combination of both visual (flashing lights) and audible (siren, buzzer or horn) alarm systems provide the best protection.
>
> Alarm systems should be automatic. They should be constructed and located so that they provide a recognizable audible or visual signal to workers. Audible devices should have a distinctive sound and be able to be heard above the surrounding noise, including the noise of the machine being operated.
>
> An alarm system is not required if moving machine parts that could endanger workers are guarded.

In a similar regulation, the *Ontario Occupational Health and Safety Act, R.R.O. 1990, Regulation 851 Industrial Establishments* removes the option for manual control by requiring automatic warnings:

> 33. Portions of conveyors or other moving machinery that are not visible from the control station, and where starting up may endanger any worker, shall be equipped with automatic start-up warning devices.

The Health, Safety and Reclamation Code for Mines in British Columbia gets more specific with its requirements in *Conveyor Belts 4.4.16:*

> (5) On every conveyor which can be started automatically by remote control or where the operator has limited visibility of the whole conveyor, an audible start up warning device shall be installed and there shall be a time delay of at least 10 seconds between the end of a minimum 10 second warning and conveyor start up.

Other provinces provide similar instructions through their individual regulatory agencies.

Quebec's *Regulation respecting occupational health and safety in mines* notes in *section 3, Conveyors, subsection 373* that every conveyor shall:

> (6) be equipped, where it is self-starting or remote starting or is partially invisible from the operator's controls and has accessible moveable parts, with a lighting device or an auditory device that signals the conveyor's start-up to the workers;

Europe

European Norm *EN 620* section 5.7.2.6 Start function states:

> If starting mechanical handling equipment may result in a hazardous condi-

> tion, then a 3 s [second] long unambiguous auditory warning shall be given 10 s [seconds] before the start and/or a visual warning signal, such as a flashing lamp, shall be provided in accordance with *EN 457:1992, EN 842:1996*, and *EN 61310-1:1995*, as appropriate.

The referenced additional standards are:

- *EN 457:1992 Safety of machinery. Auditory danger signals. General requirements, design and testing.*
- *EN 842:1996 Safety of machinery. Visual danger signals. General requirements, design and testing.*
- *EN 61310-1:1995 Safety of machinery. Indication, marking and actuation. Requirements for visual, auditory and tactile signal.*

EN 620 continues in section 5.7.2.6 with:

> Such signals shall be provided for example, in situations where mechanical handling equipment is out of sight of the operator, or when it is necessary to warn persons who may be in the working or traffic areas, that a particular conveyor or mechanism is about to start.
>
> Where a conveyor is arranged to feed onto other conveyors, starting shall be co-ordinated by the use of suitable interlocks. Suitable interlocks shall ensure correct sequential starting and prevent conveyors being fed which are not in operation or which are already operating fully loaded.

A supplier's catalog, [The Complete Spectrum of Signaling Technology, (Edition 14)] from Pfannenberg GmbH Electro-Technology for Industry, notes that *EN 54-23 Fire alarm devices – Visual alarm devices* requires the following specifications for visual signaling devices:

- An illumination intensity of min. 0.4 lux (lm/m²) is required over the entire coverage volume, i.e. the space in which the alarm signal is to be effective (e.g. production facilities).
- The visual signaling device must emit white or red flashing light.
- The flash rate must be between 0.5 Hz and 2 Hz.

Russia/Commonwealth of Independent States (CIS)

In Russia and the other members of the Commonwealth of Independent States (CIS), *GOST 12.2.022 Occupational Safety Standards System. Conveyors. General Safety Requirements* allow the start-up warning to be a signal, sound, or light. The regulation does not list a specific duration for the warning signal but does require that the system incorporate two-way communication, allowing an affirmative response prior to start-up.

> 3.10 On parts of a line of conveyers that are outside the visibility zone of an operator from the control board, a two-way warning pre-startup signal, sound or light, shall be installed, which shall be switched on automatically before the conveyer's drive is switched on.
>
> The two-way signal system shall ensure not only that persons outside the visibility zone from the conveyer's control board are notified that the conveyer is about to start up, but also that an response signal from parts of a line invisible to an operator can be sent to the control board informing that the conveyer is ready to start up.

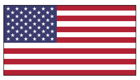
South Africa

In its guideline, *Safety Around Belt Conveyors*, the trade association Conveyor Manufacturers Association of SA Limited specifies there should be no motion until after the warning signal, but offers no guidance on the specific nature of the audible or visible signals.

The *Mine Health and Safety Act 1996* as revised in 2011 section *8.9(1)* states:

> (f) one or more devices are fitted and used to give all persons at any point where access to the conveyer belt

installation is possible sufficient prior warning for a period to be determined by the mines risk assessment with a minimum period of 10 seconds that any part of such a conveyer belt installation is about to be put into motion;



United States

In the United States, Occupational Safety and Health Administration (OSHA) requires an audible signal before starting any conveyor. In *29 CFR 1926.555(a)(1)* the OSHA standard notes "… Conveyor systems shall be equipped with an audible warning signal to be sounded immediately before starting up the conveyor."

In the metal and non-metal facilities (both above- and below-ground) in the United States governed by MSHA, *(30 CFR) sections 56.14201* and *57.14201* Conveyor start-up warnings lists the following requirements:

(a) When the entire length of a conveyor is visible from the starting switch, the conveyor operator shall visually check to make certain that all persons are in the clear before starting the conveyor.

(b) When the entire length of the conveyor is not visible from the starting switch, a system which provides visible or audible warning shall be installed and operated to warn persons that the conveyor will be started. Within 30 seconds after the warning is given, the conveyor shall be started or a second warning shall be given.

In the United States, there is no regulation on the timing of the alarm, the requirement is only that there must be a prestart warning. As one participant in the *cr4.globalspec.com Conveyor User Forum* noted, "the warning does not need to be a horn, it can be someone shouting if it is a small operation!"

Alarms

Manual or Automatic Alarm

The standards for start-up warnings have been uniformly interpreted by MSHA, and its predecessor organizations in the United States, and similar regulatory groups to include both automatic and manual conveyor-alarm systems, as long as these systems are used at each conveyor or series of conveyors within a system.

MSHA and many mine operators believe that an automatic warning and start-up system is more effective than a manual system and should be the preferred system. An automatic alarm system first sounds the start-up horn before actually setting the conveyor in motion. An automated sequence guarantees that the horn will provide a warning prior to energy being transmitted to the conveyor motor, eliminating the chance a worker will neglect to activate the alarm prior to starting the conveyor.

A manual conveyor alarm system is one which actuates an audible alarm by an independent switch, and then uses a separate switch to start the conveyor. It may be considered 'positive' and in compliance with the standard provided the system is capable of effectively warning persons prior to the time the conveyor will be started. Operators should be instructed to sound the alarm, and then assure that persons are clear, before activating the separate switch that starts the conveyor system.

In *CFR 30 56.14201(a)*, the MSHA standard exempts those conveyor systems that are entirely visible from the start-up switch from the requirements of a positive start-up warning system. However, MSHA recommends that all conveyor systems have a positive audible or visible start-up warning even when they are visible from the start-up switch. This eliminates the risk of human error where a worker starts the conveyor without checking for workers.

In some operations, the horn is sounded manually, and the conveyor starts afterward under operator control. The horn is a manual process; the operator must physically push the horn button and then release it to activate the conveyor start button. The two controls are often interlocked so they cannot be pressed simultaneously.

Particular attention must be given to the overall effectiveness of the audible warning system, to be certain that the warning is effective at each and every conveyor in the system. This does not mean that a separate horn or similar device must be installed for each conveyor, but it does mean that the warning must be positive and effective for each conveyor or series of conveyors capable of being shut down or started independently within the system.

Alarms for Conveyors that Cycle ON and OFF Automatically

In a clarification published as a *Program Information Bulletin* in March 2012, MSHA noted the conveyor start-up regulations in *30 CFR 56.14201* and *57.14201*:

> ... apply to conveyors that are operated manually and to conveyors that are operated automatically, including automatic systems controlled by a computer, such as a programmable logic controller.

Figure 5.2.

There are many styles of start-up alarms available.

Figure 5.3.

No matter what type of alarm is used, the key criteria is that it be loud enough to be heard over the general noise of the operation.

In applying the standards to conveyors that are automatically stopped and started as part of a regular production cycle, MSHA enforcement personnel were instructed to consider the period of time the conveyor is stopped. If the stoppage is long enough that workers might believe the conveyor was shut off 'intentionally and would anticipate a warning will be given' before restart, the requirement for adequate warnings will be enforced.

The Nature of an Audible Alarm

The OSHA standards in the United States, and many other standards, require an audible signal, but there is little other guidance or specifications given in the regulations. (**Figure 5.2.**)

Based on a review of literature, considerations for effective audible start-up alarms include:

- Make sure the conveyor alarm is audible above the ambient plant noise (the noise of surrounding equipment/process including the occasional presence of heavy equipment in the area).
- Make sure the alarm is a unique sound so that workers and visitors will know that some equipment is starting up and not the same bell or siren used to indicate a coffee break or lunch.
- The conveyor (or any plant equipment using a prestart alarm) should start at the end of the warning.

The duration of the warning signal should be determined by the length of time it would take for anyone who is endangered by an activated conveyor system to move to safety.

In those areas where the length and intensity of the sound for start-up alarms is not specified, a good practice would be to consider the alarms as similar to, and yet distinct from, the signals used at the start of other stationary equipment and at the movement of self-propelled mobile equipment in the plant.

As one plant official noted:

> All our start-up alarms are the same, but also unique to other alarms such as process [upset] alarms. When the workers hear this sound, they will know something is about to start and get them thinking as to where they are situated.

As to the length of the alarm, opinions are all significantly varied. Anecdotal evidence from internet forums notes warning times range from five seconds to 30 seconds. (**See Anecdotal Practices for Start-Up Warnings from Online Forums.**)

Perhaps the safest rule is that the length of warning should be guided by how long it would take an aware person to react and clear the danger area. The key consideration is to provide enough time for a worker who is otherwise busy on or close to a hazard to stop work, extricate from the hazard, radio the control room, or pull the emergency-stop cord to indicate an unsafe condition for start-up.

It seems obvious the alarm must complete the sounding cycle prior to start of conveyor motion, because in the words of one writer in the online *cr4.globalspec.com Conveyor User Forum*, if it does not, "you couldn't very well call it a 'PRE-START' alarm, could you?"

How Loud Should the Alarm Be?

When asked how long a man's legs should be, Abraham Lincoln is reputed to have replied, "Long enough to reach the ground." When considering how loud a start-up alarm should be, the same approach should be used: loud enough to be heard. (**Figure 5.3.**)

The *MSHA Hazard Alert on Conveyor Startup Fatalities* combines the instruction a plant should "provide a pre-startup alarm," with the additional bullet point that the alarm should be "loud enough to be heard." The document also notes: "Sound the alarm before conveyor startup."

A supplier's catalog, [The Complete Spectrum of Signaling Technology, (Edition 14)] from

2

Anecdotal Practices for Start-Up Warnings from Online Forums

In online forums, personnel from plants around the world compared their plant's start-up warnings. The following are extracted from the discussion.

∞

"… 30 seconds audible and visual pre-start alarm then immediate start."

∞

"We are going for 10 seconds then immediate start. 10 seconds on this site will allow enough time for any personnel to get clear of the equipment."

∞

"Most of the time, we had a ten second warning before the belt would actually start."

∞

"I have seen some where the operator had to hold the start button until motion begins."

∞

"… sound an alarm whenever someone puts the conveyor system in automatic and hits the start PB [power button]. A very loud general alarm and flashing light operates at the control panel and usually somewhere at the other remote end. After 5 seconds of alarm, the conveyor start[s]. I am thinking of changing this just a little to require that the first push of the button sounds the alarm and either the operator holds the button for 5 seconds or the system will require another push after 5 seconds but before 8 seconds (that way if someone yells something, the system won't just start)."

Pfannenberg GmbH Electro-Technology for Industry, suggests:

- According to the *EN ISO 7731* standard (replacement for *EN 457*), a sounder should have a minimum sound level of 65 dB (A).
- According to *DIN VDE 0833/EN 60849* an alarm for evacuation must be at least 10 dB(A) over the ambient noise level.

The location of the alarm should be such that people are not normally working or traveling directly in front of the alarm.

Calculating the sound pressure level at a specific distance from an alarm can be complicated in enclosed spaces with many noise sources, as is often the case in bulk-materials-handling operations.

Because predicting sound levels in mining and industrial settings is difficult, a sound engineer should be used to determine the number and location of alarms. Many of the audible alarms on the market are now programmable to allow some adjustment of the dBA level and to offer a number of signal patterns.

Adding Lights to the Sound

Although many standards allow either an audible or visible warning system, visual warnings in bright sunlight or other well-lighted places are ineffective. For this reason, it is recommended that an audible warning system be used throughout a conveyor system located in bright sunlight or other well-lighted places. The use of flashing lights can improve the alarm effect.

Some conveyor users and safety personnel argue that an audible alarm is not sufficient by itself. The alarm horn should be accompanied by warning lights along the unit that is switched on. The 'ON' cycle for the lights should be the same as the timing for the audible warning.

After the Siren Stops

Any equipment that requires a warning motion alarm that sounds prior to the motion should not move while the alarm is sounding. There should also be a delay for personnel to get clear after the sounding of the alarm. That length of time would vary for different environments.

The MSHA regulation *30 CFR sections 56/57.14201* notes that if the belt does not start within 30 seconds of the end of the alarm, the alarm should be sounded again prior to the actual start of motion.

BEST PRACTICES
Start-Up Warnings

Start-up warnings are often ineffective due to installation location, type of warning, or inspection and servicing failures. In other cases, more time is needed than required in the regulations to evacuate a confined space before the conveyor starts. The practice of depending solely on visual verification that the conveyor is clear is problematic. Even on short conveyors, it is difficult to confirm that no persons are present. Visual confirmation is highly dependent on the operators' due diligence and vision, which is often affected by distractions, lighting problems, and dust levels in the conveyor gallery. For this reason the practice of visual verification should be discontinued as the primary or sole level of protection for start-up warnings. Take these steps to help protect workers around conveyors:

- Install a sufficient number of visual and audible start-up and shutdown warnings appropriate for the local natural and machine environment so that at least one warning device is visible and audible from any position around the conveyor and associated equipment.
- Confirm verbally with workers in the area that they are clear of the conveyor before starting.
- Ensure the volume of an audible start-up alarm is at least 10 dBA over ambient sound.
- Activate start-up warnings for a minimum of 20 seconds before starting the conveyor.

Adjust the length of the start-up warning for more than 20 seconds for areas and equipment arrangements that require more than 20 seconds to clear.

- Inspect and test the start-up warnings monthly and record the results. Repair start-up warnings found to be inoperative or ineffective immediately and prior to restarting the conveyor.

CLOSING THOUGHTS
Safety is Sound (and Light)

The addition of audible and/or visual warning alarms and properly sequenced time delays is a safeguard that is appropriate and required to protect employees working on or around conveyor belts or moving machinery. (**Figure 5.4.**)

In the industrial environment, if a worker is not the one actually pushing the start button, the individual will probably not know that it is about to start. The alarms are essential to let anyone in the proximity of equipment know that it is about to start. ⚠

Figure 5.4.

Start-up alarm powered by conveyor junction box.

2

Chapter 6 Pull-Rope Emergency-Stop Switches

INTRODUCTION

The Need for Emergency-Stop Controls

As defined in *ISO 13850 Safety of Machinery – Emergency Stop – Principles for Design*, the function of any Emergency-Stop Switch is to:

> …avert arising or reduce existing hazards to persons, damage to machinery or to work in progress, and can … be initiated by a single human action when the normal stopping function is inadequate for this purpose.

If a worker can access a conveyor in operation, it must be equipped with an emergency shutdown device along the full length of the conveyor. If both sides are accessible—either at ground level, or via walkways—both sides should be equipped with the shutdown mechanism.

Most industrial control emergency-stop switches—a name often shortened to 'e-stop'—appear as a 'palm push button' or 'panic button' that a simple hand strike will activate to stop the equipment or process in question. In a control room setting, the e-stop will appear as that button. But along the run of a belt conveyor, the emergency-stop function is provided by pull-rope emergency-stop switches.

Pull-rope stop switches are a safety mechanism that allows a worker at any point along the side(s) of the conveyor to pull a cable to shut off the conveyor power and stop the belt motion. (**Figure 6.1.**) The switches are like the 'Stop Here' cord on a bus or train, except the switch does not wait for the driver to shut off the power, but rather does it automatically. With a pull of the cable (in any direction) at any point along the conveyor, the switch interrupts the conveyor drive's electrical circuit and shuts down the system.

Pulling on the cord stops the operation of a conveyer belt by applying force (pulling) to the pull cord to activate a mechanical arm which is mechanically linked to a normally closed electrical switch(es). (**Figure 6.2.**) The switch(es) is interlocked with the conveyor drive-control circuit. When sufficient force is applied to the pull cord, the switch is deactivated, causing the conveyor's main drive to be de-energized, thus allowing the conveyor belt to drift to a stop. The mechanical arm often doubles as a visual sign that the switch has been tripped; sometimes the switches have additional 'flag' mechanisms. Safety switches will often have auxiliary contacts for interfacing with other system logic or communication needs, such as locating a specific switch on a long conveyor.

Pull-cord switches are actuated in two basic situations or conditions. The first situation is when a worker, or the worker's clothing or tool, becomes entrapped in the conveyor. Unfortunately, this entrapment has caused a significant number of serious and fatal accidents on conveyors. The use of a pull-cord switch in these circumstances can reduce the severity of an injury but generally does not prevent the unsafe condition and some degree of injury from occurring.

The second situation is when a worker observes a problem with the conveyor and stops the conveyor to inspect or prevent damage to the conveyor or conveyor components. Using the emergency pull-cord stop switch in this manner as a convenient means of shutting down the conveyor when doing inspections, adjustments, or minor repairs is a common, if unfortunate, practice. It is not necessarily a proper or safe use of the switch, but it does occur in real life. A pulled cord should never

Figure 6.1.

Installed beside the conveyor, pull-rope emergency-stop switches allow workers to stop the belt from any point along the run of the conveyor.

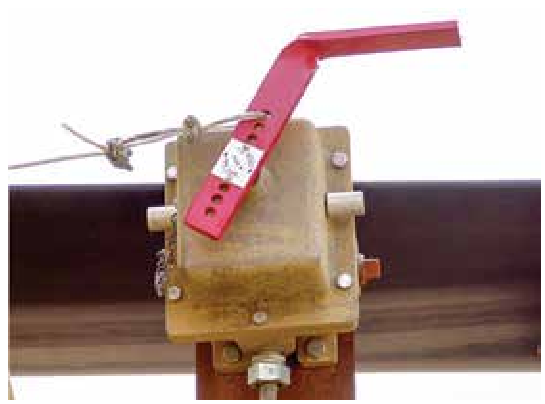


Figure 6.2.

A pull on the stop switch's cable moves an arm that opens a normally closed electrical switch, cutting off power to the conveyor. This switch seems to be missing the cable to the right. In addition, the cable clip to left is incorrectly installed.

A Note on Nomenclature

For the purposes of this book, we consider these terms synonymous: emergency-stop switch, e-stop, and safety switch. We also consider these terms synonymous with each other: pull rope, pull wire, pull cord, pul key, and grab wire.

A pull-rope switch is one form of emergency-stop switch; an emergency-stop switch may be, but is not necessarily a pull-rope switch.

substitute for proper (non-emergency) conveyor stopping practices, including a Lockout / Tagout procedure.

The Basics of Conveyor Stop Controls

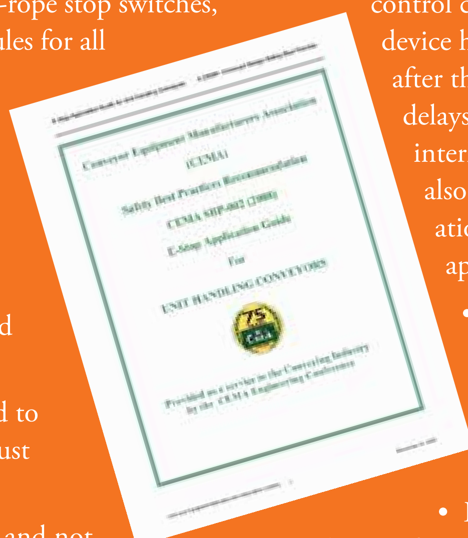
Emergency-stop devices—including pull-rope switches—should be located at each operator control station and at other locations, such as along the conveyor. They shall be positioned for easy access and for non-hazardous operation by the operator and others who may need to operate them. Measures against inadvertent operation should not impair accessibility.

The device must be capable of initiating the stopping of the machinery and equipment in a controlled manner without creating any new hazards.

Many shorter in-plant conveyors will have e-stop switches installed at the motor control station. E-stops are red in color with a yellow background according to the National

CEMA's E-Stop Application Guide

In 2008, the Conveyor Equipment Manufacturers Association (CEMA) published *Safety Best Practices Recommendation E-Stop Application Guide for Unit Handling Conveyors*. While this publication does not focus on pull-rope stop switches, it does list some general applications rules for all e-stops as follows:


Conveyor Equipment Manufacturers Association
(CEMA)
Safety Best Practices Recommendation
CEMA SBP-002 (2008)
E-Stop Application Guide
For
UNIT HANDLING CONVEYORS

Provided as a service to the Conveying Industry
by the CEMA Engineering Conference

- An E-Stop must be provided at reasonable intervals consistent with equipment type and density, expected operating parameters, reasonable foreseeable misuse and training levels of personnel expected to be in the area.
- E-Stops are not properly configured to function as lockout devices, and must never be used for that purpose.
- E-Stop circuits must be hard wired and not depend on any solid state or logic devices to function. Approved networking systems may be employed provided any programming changes are indelibly recorded.
- E-Stop circuits, when activated, shall remove electrical energy directly from the power source or from the power source switching device.
- E-Stop circuits shall stop air or hydraulic powered devices by interrupting the power source in such a manner that subsequent motion due to kinetic energy or other means does not occur.
- E-Stop electrical devices must be designed such that they require manual reset at the point of electrical actuation before a restart sequence can begin.
- Resetting the activated E-Stop device must not automatically restart the equipment. Equipment restart must be initiated by start controls of the associated control cabinet only after the activated E-Stop device has been manually reset, and begin only after the normal startup sequence including delays and warnings have occurred. Equipment interlocked with the associated cabinet will also restart (or not) per the sequence of operation. No equipment will restart without appropriate warning and delay.
- Apply only those E-Stop devices and systems that meet accepted company, industry, engineering, and government standards for performance, appearance, and electrical design.
- E-Stop switches must be recognizable and distinct from any other controls:
  - The actuator of a pushbutton-operated device shall be of the palm or mushroom head type.
  - E-Stop pushbutton actuators shall be colored red.
  - Pull cords for pull cord switches shall be provided in a high visibility color which allows rapid identification.
- E-Stop devices and systems, regardless of type, will effectively stop all motion in the controlled E-Stop zone.

As this was written, CEMA is updating its E-Stop Application Guide (CEMA SBP-002). It is anticipated this 2016 edition, which will include "Guidelines Specific to Bulk Handling Conveyors," will be available for free download from cemanet.org.

Fire Protection Agency (NFPA) and may be a push button or mushroom-head style. The e-stop performs the same function as a pull-cord stop, disconnecting the power from the conveyor drive, and after resetting, requires a secondary command to start the conveyor.

Emergency-stop push buttons or any other such components must be safely and easily accessible to operators and workers on site.

Push buttons, levers, or any other components used as actuators of an emergency-stop device must be designed and installed so that they can be distinctly and visually identified and easily operated. (**Figure 6.3.**)

Any action on an actuator resulting in an emergency-stop command shall also result in the latching-in of the control device. The emergency-stop command must be maintained until the control device is reset. The resetting operation for an emergency stop must be possible only at the position where the emergency stop was initiated. Resetting an emergency stop must not cause the machinery or equipment to immediately restart.

It is important that pull-rope switches and other e-stop systems be reserved for emergency use; they should not be employed for system lockout or 'routine' starting and stopping of the conveyor system. It is also important to remember the emergency-stop function shall not be used as a substitute for safeguarding measures and other safety-critical functions but instead is intended only as a backup measure.

How Pull-Rope Switches Work

The pull-rope emergency-stop switch is actuated by a movement of a cable (pull cord) that is installed alongside the conveyor and connected to the switch. (**Figure 6.4.**) This 'pull cord'—typically a sheathed metal-strand cable—runs through mounting rings attached to the conveyor structure.

A pull of the cable in any direction shall activate the emergency-stop switch. A failure of the spring tensioning system or a break in the cord itself will also activate the switch to shut off power to the conveyor and trigger an emergency stop. The cable must be able to resist a tension force 10 times greater than the tension required to activate the emergency shutdown switch, without breaking.

Figure 6.3.

This red mushroom-head-style switch allows easy identification and operation of an emergency-stop switch.

Figure 6.4.

The pull-rope emergency-stop cable is installed alongside the conveyor. Note that the cable has slipped out of the support rings in the right foreground; this should be fixed.

Advancements in Network Control

As control systems advance, the use of software to monitor the status of safety devices such as pull cords is becoming more common. Network technologies have advanced to the point where they are as reliable as hardwired e-stop circuits and actually provide a greater range of functionality in terms of flexibility, fault-reporting diagnostics, and historical error logs. These network technologies are now used extensively in unit handling conveyor applications, and it can be expected that this technology will be applied to bulk-materials-handling conveyors. For more information, *IEC Standard 61508* stipulates the general requirements for electrical, electronic, and programmable safety devices.

2

2

With the pull-rope system aligned, the emergency-stop signal can be triggered from anywhere along the run of cable. This can be a distance of up to about 50 meters [≈165 ft] on each side of the switch, depending on manufacturer recommendations and the specifics of the installation and local regulations.

The emergency-stop grab wire should be easily accessible during normal work operation along a conveyor, to allow a pull on the cord in any direction to stop the belt.

A horizontal force of less than 125 newtons [≈28.5 lb_f], when applied midway between two support rings and perpendicular to the cable, must be sufficient to activate an emergency stop. The required movement of the cable between the 'at rest' position and the activation point typically must not exceed 300 millimeters [≈12 in.].

There are single-direction switches that allow the cord to be run out in one direction only, and dual-direction switches where the cord is symmetrically stretched and tensioned in two directions.

The switch has a positive mechanical linkage between the switch contacts and the wire rope. This means, on pulling or breakage (tension loss) of the wire, the safety contacts are positively opened. When the cable is pulled a sufficient distance, it pivots or rotates an actuating arm inside the switch far enough to break the power circuit, opening the normally closed contacts. Opening the contacts generally requires a movement on the order of 25 millimeters [≈1 in.] or 20 to 25 degrees of rotation of the actuating arm.

Upon actuation, the switches are then mechanically latched and can then only be returned to the operational condition by pressing a reset button or actuating a lever. The reset lever keeps the switch locked in an alarm condition until it is manually reset by an operator. Pressing down on the reset lever will bring the lever back to the upright position and will release the lock.

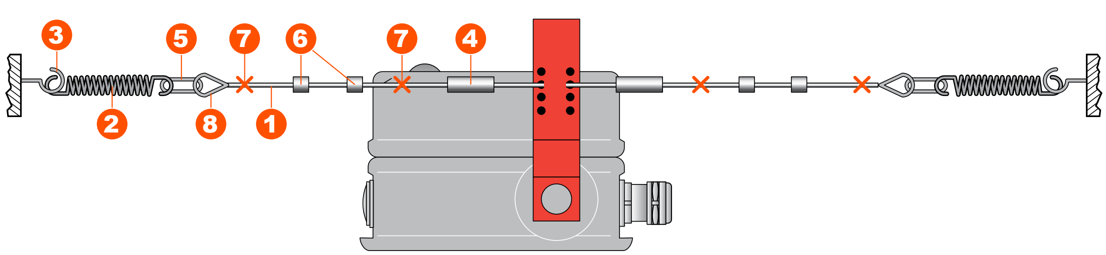
In order to restart the conveyor, two things have to happen. First, the emergency-stop pull cord or push button at the conveyor is reset, and then secondly, the start button at the control panel is activated. Once the system has been reset, normal start sequences should occur. This would include the sounding of warning horns prior to the belt beginning to move.

The stop switch can be connected to an audible or visual signal or alarm which indicates the switch's activation, and resulting shutdown of the conveyor. A 'flag' or light may also be included on the exterior of the switch to provide an indication of which switch was tripped.

In addition to the pull cord, some emergency -stop switches also feature an additional external stop button.

Pull-Cord Systems

As with all electrical systems and controls, correct installation is required to provide proper operation of pull-cord e-stops. Emergency-stop buttons and pull ropes must comply with regional and local electrical codes, as they may impose additional requirements for the circuits of the emergency-stop system.



1. Pull Rope
2. Tension Spring
3. Anchor Hook
4. Tensioning Element
5. Quick Link
6. Rope Support
7. Rope Clamp
8. Thimble

Figure 6.5.

Components of a typical pull-rope stop-switch system keep the cable taut and suspended between both ends of the system and connect the switch(es) along the run of the conveyor.

In the event of a power loss to the emergency-stop circuit, all system circuits should fail, shutting off the conveyor.

In addition to the issues of correct wiring and operation of the electrical switch, pull-rope emergency stops have the complicating factor of the installation and maintenance of the pull rope(s).

The cable is connected to the switch(es) and may employ springs or turnbuckles to maintain the proper tension or degree of tautness in the line. (**Figure 6.5.**) Some switches have a tension indicator on the switch housing. The cable must move freely within its supports, particularly at bends. Cables must not be twisted nor suffer the risk of being twisted during use.

The cable should be installed without too much slack in the cable, as extra slack will increase the distance of 'pull' required to activate the switch and shut off the conveyor. (**Figure 6.6.**)

The overall cable length from a single two-direction switch generally should not exceed 100 meters [≈330 ft], with 50 meters [≈165 ft] on each side of the switch. Distance between cable support rings is usually in the 2 to 3 meter [≈6 to 10 ft] range.

One reason for the switch to be centered between the end points—that is, with equal lengths of line on both sides of the switch—is so that variations in thermal expansion do not adversely affect the pull length of the cord required to stop the conveyor. A deviation of up to three percent in line length is typically allowed.

The cable can be installed so it runs around the end of a conveyor using a corner pulley when installed according to manufacturer's instructions.

Specifications for the number of switches required, the maximum cable length, the number and spacing of support rings, and other characteristics must conform to the recommendations of the switch manufacturer.

The Need for Testing

An August 1995 *Rock Products* magazine article, Rock Newscope, by Bob Drake reported that the Mine Safety and Health Administration (MSHA) in the United States alerted mine operators about potential failures of emergency-stop pull-cord systems along conveyors. Following tests of over 1,100 systems, MSHA noted a two percent failure rate. MSHA attributed these problems to a number of factors:

- Spillage around the switch that prevented deactivation of the conveyor
- Broken pull cords or excessive slack in cords
- Frozen pivot bearings where the switch shaft enters the enclosure
- Failure of electrical switches inside the enclosure
- Incorrect wiring of switch or control circuits

Two percent might not seem a high percentage for system failures, until it is that system on which a worker's life depends. If a platoon of 50 paratroopers jump out of an aircraft, a failure rate of two percent means that one soldier will have a parachute that does not open. This is obviously a tragedy for the one soldier, and may well interfere with the success of the overall mission. An e-stop is like a parachute; it needs to work first time, every time.

The solution to the problem of the failures in pull-rope safety switch performance is proper

Figure 6.6.

When the cable has too much slack, workers will not be able to pull the cord far enough to stop the belt to save themselves or a co-worker.

2

maintenance and equipment testing programs where the operation of the conveyor safety equipment is checked. These tests should be performed on a monthly basis.

MSHA affirmed the need for monthly inspection and testing of safety switches in *Program Policy Letter No. P12-V-02*, issued in April 2012. This letter confirmed that MSHA considers emergency-stop devices or cords as electrical equipment under *30 CFR section 77.502* and so "must be examined, tested, and maintained by a qualified person to assure safe operating conditions."

The letter noted that on February 3, 2009:

> ... an Administrative Law Judge (ALJ) accepted the Secretary's interpretation that an emergency stop device comprised of a pull cord switch and its mechanical activating arm is included in the definition of electric equipment ... The ALJ also found that testing must include a functional test and not be limited to visual observation.

The letter added that *30 CFR section 77.502-2*:

> ... requires that such examination and testing be conducted at least monthly."

The Program Policy Letter noted:

> ... although examination of the emergency pull cord switches and mechanical arms does not have to be recorded during the monthly examinations of electrical equipment, a record of defective switches and arms must be kept.

Consequently, in those work areas in the United States under the jurisdiction of MSHA, a monthly 'working test' of all conveyor pull-rope emergency-stop systems is required. Records of the results should be kept. While United States workplaces not under MSHA guidelines—and workplaces in other geographic locations—may not have this as a formal requirement, it is certainly a good practice.

Meanwhile, in Australia

A similar problem was noted by the Queensland (Australia) Department of Natural Resources and Mines in its *Safety Bulletin No. 40, Testing Of Conveyor Pull Wire Activated Emergency Stops*, issued March 25, 2003.

The bulletin noted:

> ... a number of recent structured inspections has found testing of pull wire activated emergency stops has either not been sufficient or has not been undertaken correctly. Most testing was found to involve simply pulling the pull wire in one direction as hard as required to activate the emergency stop. This basic test fails to test a number of other key requirements of pull wire activated emergency stops.

The *Safety Bulletin* affirmed that "tests carried out on conveyor pull wire activated devices should ensure all requirements" of the Australian standard are taken into account. [The standard cited in the published bulletin—*AS 1755*—has been superseded by *AS/NZS 4024.3610*, which discusses pull wire emergency stops in section 2.10.6. – Ed.]

The *Safety Bulletin* concludes:

> The results of any service, maintenance and testing of conveyor pull wire switches should be kept as a record, not only to verify the testing but to monitor any deterioration that may cause an unacceptable level of risk.

Pull-Rope Switches and Human Reaction Time

So assuming a conveyor's pull-rope stop switches are properly specified, placed, installed, maintained, and operational, they will be sufficient to provide safe working conditions for workers, right?

Well, not so fast.

Even with proper installation, inspection, and operation, a pull-cord stop switch on a belt conveyor might not stop the belt fast enough to save a life.

The problem comes in the relatively high speeds of modern belt conveyors. Many conveyors are designed for a controlled stop under normal conditions to limit dynamic forces and for an emergency stop in emergency situations. The time it takes to stop a conveyor under a controlled stop can be on the order of 10 to 60 seconds. In an emergency-stop configuration, the conveyor can stop more quickly but it still takes time. When compared to human reaction time—specifically the reaction time of a worker who is caught in a pinch point or other hazard—the belt can travel a significant distance before the human reacts. The worker will probably not have sufficient time and ability to pull the rope to activate the stop function in order to avoid injury or death.

The following is a typical accident scenario:

A worker is using a long-handled tool (a broom or shovel) to clean near the return rollers on a belt conveyor. The belt is moving at a speed of 1.5 meters per second [≈300 fpm].

The worker pushes the tip of the tool against the moving belt, which catches and pulls the shovel—and the worker holding it—toward the nip point between the roller and the moving belt.

Can the worker save himself? Could the worker just let go of the tool? Could the worker activate a pull-rope emergency-stop switch to stop the moving belt so the tool falls out?

The answer to all three questions is a resounding "No."

Even at the relatively modest conveyor speed of 1.5 meters per second [≈300 fpm], the belt—and the conveyor's other rolling components—are moving too fast for the worker to release the shovel in time to escape without entanglement and serious injury.

Research published in a 2012 paper, *Start Reaction Time and Performance at the Sprint Events in the Olympic Games,* indicates that an Olympic sprinter's average reaction time to the starter's gun is 0.146 to 0.18 seconds before the athlete begins to move. That is very quick. But even with the relatively modest conveyor speed of 1.5 meters per second [≈300 fpm], the moving belt will have pulled the tool from 0.219 to 0.27 meter [≈8.6 to 10.6 in.] before the highly trained and alert world-class sprinter could react to let go of the tool.

A 'regular' worker—one who is not a world-class athlete—would require a longer time to react, and so be pulled farther into the rotating equipment before being able to let go.

The problem is like driving. The question is not just when the driver sees a problem, it is how fast the individual recognizes the situation as a problem, and then how long it takes to initiate the proper reaction to correct the problem.

'Perception time' is how long the driver takes to recognize the hazard, so the brain realizes it requires an immediate reaction. This can be as long as ¼ to ½ of a second. Once the brain realizes 'danger,' the 'reaction time' is how long the body then takes to execute the corrective action. In the case of driving, this is the time to move the foot from accelerator to brake pedal. This reaction time can vary from ¼ to ¾ of a second. The total time to save oneself following an unexpected stimulus is the sum of the two parts—perception time and reaction time. The total time often adds up to approximately one second.

If we continue to assume the 'fairly slow' belt speed—1.5 meters per second [≈300 feet per minute]—cited above, the belt moves 1.5 meters [≈5 ft] a second. If a worker is caught, during the one second it takes the average worker to 'perceive' and 'react' to what is happening, the belt pulls him 1.5 meters or 5 feet. That is far enough to draw in the worker's tool, and the worker's arm or body into the pinch point before the worker can react.

If the belt speed is faster—and the conveyor belts in many operations runs at speeds of two or three times the 1.5 meters per second [≈300 fpm] speed selected for this example—the distance the trapped worker is pulled into the hazard is multiplied by the same factor. (**Figure 6.7.**)

In either case, the worker has probably already gone too far into the conveyor to reach and activate the pull-rope stop switch.

If the worker is inattentive or distracted, the reaction time will be slower and the 'pulled in' distance even greater. Other factors that can affect the average human reaction time include age, fitness, fatigue, poor vision, poor hearing, alcohol, and medication.

Even if the trapped or imperiled worker is working with a buddy, it will take that buddy a similar amount of time—if not longer—to realize what has happened, and then locate and pull the cord to actuate the conveyor stop function.

And one more problem: the location of the pull-rope emergency-stop switch on the side of the conveyor may mean a trapped worker will be unable to reach the switch. While the pull cords should be handy and accessible to workers safely on the walkway, their position might be awkward, if not unreachable, when a worker is being pulled onto the belt or into the components.

So Then, What Good are Pull-Rope Switches?

If they typically are not placed so a trapped or otherwise endangered worker can reach them, and the time required to activate them is such that they cannot prevent an injury from a moving conveyor, what purpose do pull-rope stop switches serve? Here are a few answers.

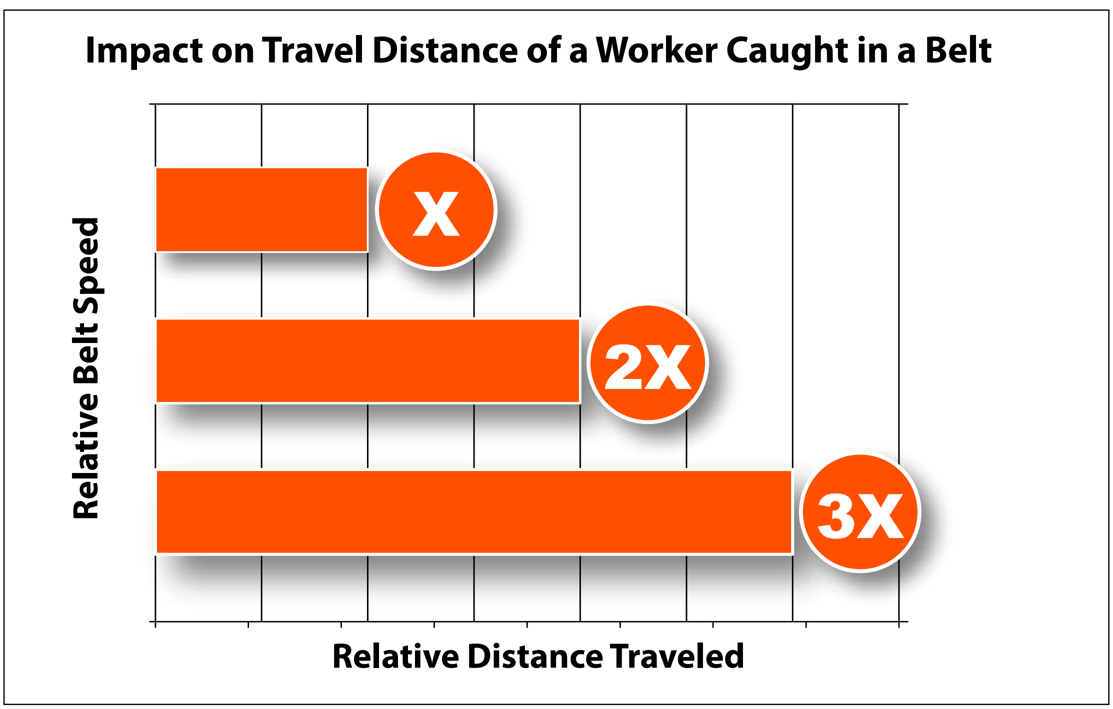
In plants where the 'buddy system' or 'two-man rule' allows or requires two employees to work closely together so that they are able to monitor and help each other, the second worker can react to an emergency by pulling the rope to shut off the conveyor and save the life (if not the arm) of the 'buddy.'

Another possible benefit of pull-rope switches is that they can be used if a worker is in the danger zone around a conveyor when the warning horn announcing an imminent conveyor start is sounded. Given the typical 10- to 30-second duration of that alarm, the signal provides enough time for a worker to reach the

2

Figure 6.7.

As belt speed increases, so does the distance a trapped worker will be pulled into the conveyor system, significantly increasing the chance of serious injury.



pull cord and pull it, de-energizing the drive before the conveyor can start and create a hazardous situation.

It may be that the best function of pull-rope switches is the preservation of the conveyor system. If a worker walking the belt on an inspection tour sees a severe immediate problem that endangers personnel or equipment, the switch can be pulled to stop the conveyor without having to return to the control room. That way, damage can be minimized and repairs made without continuing the operation that poses a risk to the conveyor equipment.

In some ways, the pull-cord e-stops are more about preserving the equipment than reducing risk to workers.

Issues with Installation

Problems with pull-rope emergency switches often start with faulty installation of the switch or its critical subsystem, the pull wires.

One installation problem often seen is when the pull ropes are terminated prior to the head and tail pulleys on the conveyor structure. (**Figure 6.8.**) This reduces the protective benefit of the pull-cord switch as statistics show that a significant number of accidents happen when workers clean and perform maintenance at the head and tail pulleys. Cables should be extended around all accessible areas of the pulleys.

The cables are commonly attached to the switch using a loop secured with 'U-bolt' wire rope cable clips. It is fairly common to see incorrect installation of the clips. Care must be taken in the installation of the cable clips to avoid improper attachment. The 'U' part of the clip can crush wire strands of the load-bearing side, thereby weakening the rope. Proper installation of the cable clips is when the 'saddle' (flat side) of the clip goes onto the live end (the portion holding the load) of the cable, and the 'U' goes against the 'dead' end of the cable. The expression 'Never saddle a dead horse' is used as a memory aid for proper installation technique. (**Figure 6.9.**)

Detail for the proper number and placement of the wire rope clips is specified for the United States in the OSHA regulations *29 CFR 1926.251(c)5* and OSHA *1926.251(c)5i*. Se also *ASME B30.26 Rigging Hardware 26 – 3.1.3 Assembly Wire Rope Clips.* Poorly strung cable can also create problems. The cable must move freely within its supports, particularly at bends. Cables must not be twisted nor suffer the risk of being twisted during use.

While the mechanical life of an emergency -stop switch is typically set at 100,000 operations by its suppliers, the *IS/EC 60947 Low-Voltage Switchgear and Controlgear, Part 5* standard specifies a switch's latching mechanism is subject to an operating durability test of 6,050 operations. This emphasizes that emergency-stop switches are intended to be used only in emergencies, rather than for the common (non-emergency) shutdown of conveyor systems.

Figure 6.8.

The cables on pull-rope emergency-stop switches should not terminate prior to a pulley, but rather go all the way around the end of the conveyor.

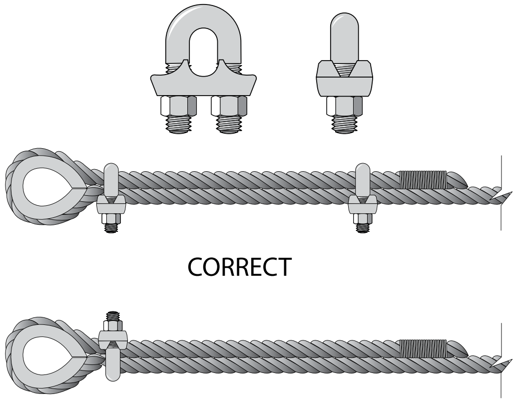


Figure 6.9.

When installing cable clips on the pull-rope stop switch wire cable, the flat side of the clip should go onto the live (connected) end of the cable.

2

Pull-cord switches are prone to false trips due to material falling from the belt, ice accumulation, and other issues. In **Figure 6.10**, the switch was purposely disabled due to numerous conveyor stops triggered by wild goats nibbling at the cable. The installation shown has other problems, including one missing cord and the improper attachment of the existing cord.

When selecting a pull-rope system, it is important to give consideration to the conditions under which the system will be established. The system often needs to stand up to challenging industrial environments, including the presence of vibration, shock, temperature extremes, dust, foreign bodies, moisture, corrosive materials, and fluids. In coal, petrochemical, and food applications where an explosive atmosphere may be present, a hazardous-duty system may be necessary.

For most applications, an IP-66 rating—that is, 'Ingress Protection' rated as dust tight and protected against heavy seas or powerful jets of water—is appropriate. This is (roughly) equivalent to a 4 or 4X enclosure rating from the National Electrical Manufacturers Association (NEMA).

Installation characteristics including maximum cable length, numbers and spacing of support rings and pulleys, variation in cable length due to temperature changes, and other criteria must conform to manufacturers' recommendations.

REGULATIONS AND STANDARDS

All countries require some type of emergency stop on bulk-materials-handling conveyors, and the pull-cord switch is the most commonly used method. The requirements vary widely in details like the spacing of switches and the amount of tension or slack in the pull cord.

Figure 6.10.

This emergency-stop switch was disabled to prevent conveyor shutdowns caused by wild animals chewing on the cables.

All regulations require that an emergency-stop command has priority over the sustaining or run function. Thus regulations require that pull-cord stop switches must be manually reset before restarting the conveyor. The resetting itself should not restart the conveyor but requires a separate start command. There are exceptions in the United States and Australia for some mines where resetting the switch is allowed to restart the conveyor.

All regulations and standards are careful to point out that emergency pull-cord switches are not a substitute for guarding.

A comparison of requirements from three jurisdictions is shown in table **Figure 6.11**.

Australia

Australian standard *AS/NZA 4024.3610 Safety of machinery – Conveyors – General Requirements*, section 2.10.3 goes into detail on the requirements for various stop switches, while section 2.10.6 covers requirements for pull-wire emergency stops.

Section 2.10.6.1 notes the universal comment that the installation of pull-rope switches should not be used as a substitute or replacement for physical guards. A note immediately following offers that the requirement for pull-wire stop switches may be supplanted by the presence of suitable stop controls if they provide a similar level of safety.

The section continues with the requirement that pull-rope stop switches shall be provided where removable guards are installed which are not interlocked to the conveyor drive—that is, where the removal of the guards does not automatically shut down the conveyor.

In section 2.10.6.1 the standard specifies that pull wires in a pull-rope stop system are red in color. A further comment notes that in situations where the red color on the wire may be difficult to see—due to environmental conditions, for instance—reflective labels will be installed at intervals of not more than 30 meter [≈100 ft] intervals, as well as at the conveyor head, tail, and transfer points, to identify the pull wire.

Section 2.10.6.2 covers the design of pull-wire stop-switch systems. It notes that any breaking, slackening, or removal of the wire shall initiate the stop command for the conveyor.

Subsection (f) mandates that the switch shall be activated (shutting down the conveyor) when the wire is pulled in any direction. The force required to operate the pull-wire device is not to exceed 70 newtons [≈15.5 lb_f] when the force is applied at right angles to the pull wire path. The movement of the wire to activate the switch should not exceed 300 millimeters [≈12 in.]

Other requirements note the material used in the pull ropes shall be strong enough and suitable for the conditions, and that operators will not need additional protection to handle the wire ropes.

The supports for the wire shall be spaced at a maximum of 6 meters [≈19.5 ft] apart, and the supports shall be designed so the wire moves freely, yet without allowing the wire to be detached from the support.

In addition, when a pull-rope stop system has more than one switch, a visual signal will be provided to indicate which switch has been used to stop the conveyor.

Section 2.10.6.3 of the *AS/NZA 4024.3610* standard discusses the location of pull wires.

2

Comparison of Requirements for Emergency Stop Pull Cord Devices

Requirement	United States MSHA 30 CFR OSHA 29 CFR	Europe EU 620	Australia AS/NZS 4024.3610
Trip Force	Not specified	125 N [≈28 lbf]	70 N [≈15.5 lbf] at a right angle to pull wire 230N [≈ 51.5 lbf] along the axis of the pull wire
Wire Movement	Not specified	300 mm [≈12 in.] maximum at midpoint	300 mm [≈12 in.] maximum
Support Spacing	Not specified	Not specified	6 m [≈19.5 ft] maximum
Height of Wire Above Working Surface	Not specified	0.6 to 1.7 m [≈23.6 to 67 in.]	0.9 to 1.5 m [≈35.4 to 59 in.]
E-Stop Exemption for Short Conveyors?	Yes	Yes < 10 m [≈32.8 ft.]	Yes Single stop control (if "easily accessible") for conveyors less than 2.5 m [≈8 ft] long
Manual Reset with Secondary Restarting Action Required?	Surface – Yes Underground – No	Surface – Yes Underground – No	Yes (except in mines where prestart warning is provided)
Visual Proof of Actuation Required?	Yes	Yes	Yes if more than 1 switch
Minimum Distance from Pull Wire to Hazard Specified?	Not specified	Not specified, but within reach of operator	Yes, less than 1 m [≈39 in.]

Metric to Imperial or Imperial to Metric conversions are rounded in the direction of greater safety.

Figure 6.11.

Comparison of requirements for emergency-stop pull-cord devices.

The requirements specify that pull wires should be installed so they are:

1. Visible;
2. Readily accessible for both a trapped individual and for an individual nearby;
3. Outside any removable guard;
4. Outside of the vertical line of any nip or shear point and 1 meter [≈39 in.] or less from the nip and shear points;
5. 900 mm [≈35.5 in.] or more above the floor;
6. Typically 1,500 mm [≈59 in.] or less above the access floor; in circumstances where the switch is required to be more than 1,500 millimeters [≈59 in.] above the floor, the pull rope shall be positioned below all nip and shear points.

The *AS/NZA 4024.3610* standard includes drawings to show the preferred location for pull-wire stop switches. The standard further instructs that a risk-assessment procedure should be used to determine the location for the switches.

Canada

According to the Canadian safety laboratory, Occupational Health and Safety Research Institute (IRSST) 2003 publication, *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*, section 373.5 of the Regulation Respecting Occupational Health and Safety in Mines states:

> All conveyors must be equipped, where the workers may access a conveyor while it is in operation, with an emergency shut-down device along its full length between the head pulley and the return pulley (tail pulley).

Under clause 4.4.3 Conveyor systems, the *CAN/CSA M421 (R2016) – Use of electricity in mines* specifies:

> *Clause 4.4.3.1*
>
> An electrically driven conveyor shall have the following:
>
> (a) pull-cords (see Clause 4.4.3.2) for stopping the conveyor at accessible location along the conveyor. The pull-cords shall be within easy reach of persons at such locations.
>
> *Clause 4.4.3.2*
>
> A pull-cord required by Clause 4.4.3.1 shall:
>
> (a) operate a manual-reset-type of switch that stops the conveyor;
>
> (b) be designed and arranged so that it operates the associated switching device and generates the emergency stop signal when
>
> (i) the pull-cord is pulled in any direction;
>
> (ii) a perpendicular pulling force of less than 200 N [≈44.9 lb_f] is applied to the pull-cord; and
>
> (iii) a perpendicular deflection of the pull-cord of less than 400 mm [≈15.75 in.] occurs;
>
> (c) be able to withstand, without breaking, a tension force ten times greater than is necessary to generate the emergency stop signal; and
>
> (d) incorporate a visual indicator to show which device has been operated where more than one switching device is necessary.

Canada is an example of a country that provides general safety guidelines on a national level while the provinces can enact more stringent regulations. For example, Alberta Occupational Health and Safety (OH&S) legislation of 2009 mirrors the national legislation but the province government sponsored a group, Workplace Health & Safety Policy and Legislation, Alberta Employment and Immigration, to complete a guide with industry contributions, *Best Practices on Conveyor Safety*, in 2003 which has become a de facto conveyor safety standard.

In section *4.4 Emergency stop pull-cords*, this publication notes:

If workers can access a conveyor in operation, it must be equipped with an emergency shutdown device along the full length of conveyor.

A sheathed metal strand cable shutdown device (pull-cord) must function as an emergency stop switch, whatever direction the cable is pulled in, or when the emergency stop switch is broken. A spring failure must also trigger an emergency stop.

A horizontal force of less than 125 N [≈28 lb_f], when applied midway between two support rings and perpendicularly to the cable, must be sufficient to activate an emergency cable. Lateral movement of the cable (between the position while at rest and the activation point) must not exceed 300 mm [≈12 in.] The cable must be able to resist a tension force 10 times greater than the tension required to activate the emergency shut-down switch, when such force is applied perpendicularly to the cable.

The cable must move freely within its supports, particularly at bends. Cables must not be twisted nor suffer the risk of being twisted during use. If a belt width is 800 mm [≈31.5 in.] or less, a single central cable may be used above the belt.

Maximum cable length and other characteristics must conform to manufacturers' recommendations (for support rings and pulley protection, freeze-up prevention, variation in length due to temperature changes, etc.)

CSA Z432-04 (R2014) Safeguarding of machinery offers the following guidance in section 7.17.3 Emergency stop pull-cords:

7.17.3.1
Emergency stop pull-cords shall be located in such a manner as to be clearly visible, readily accessible, and so positioned that they can be used not only near the operator's normal control station, but at other appropriate points.

7.17.3.2
The pull-cord system shall be designed and arranged so that it operates the associated switching device and generates the emergency stop signal when

(a) the pull-cord is pulled in any direction, a perpendicular pulling force of less than 200 N [≈44.9 lb_f] is applied to the pull-cord, and a perpendicular deflection of the pull-cord of less than 400 mm [≈15.5 in.] occurs;

(b) the pull-cord breaks; or

(c) the failure of a single spring occurs.

7.17.3.3
In addition, the pull-cord shall be able to withstand without breaking a tension force 10 times higher than that necessary for generating the emergency stop signal.

7.17.3.4
Where, in the case of long pull-cords, more than one switching device is necessary, a visual indicator shall be incorporated to show which device has been operated.

Europe

European standard *EN 13850:2006 Safety of machinery – Emergency stop – Principles for design* describes the actions required for an emergency stop (and thus for pull-rope stop) switches:

- purposeful direct human operation (through a force) for actuating:
- direct mechanical opening (latching) without the use of springs or other energy storing assistance, and;
- resetting [only manual resetting at the location where the switch was actuated] and;
- permits restarting, but does not automatically restart.

European Norm *EN 620 Continuous handling equipment and systems – Safety and EMC requirements for fixed belt conveyors for bulk materials* requires that an emergency stop "be accompanied by an unambiguous visual and/or acoustic warning."

In section 5.7.2.8 Emergency Stop System, *EN 620* then specifies:

> Emergency stop devices shall have positive operation, be self-latching and shall be either:
>
> a) one or more push button operated switches which shall be installed in such a way that at least one may be reached within 10 m [≈32.8 ft] from any accessible point of the equipment; and or
>
> b) one or more pull cord operated switches arranged along the full length of the installation; or
>
> c) the conveyor's supply disconnecting device if the distance from any accessible point of the equipment to the disconnecting device is 10 m [≈32.8 ft] or less.
>
> Emergency stop devices shall be at all control stations, working positions and at accessible parts of the machinery including loading points, unloading points, walkways and transfer points.
>
> When an emergency stop device(s) has been actuated and the conveyor has come to a halt, the conveyor shall remain in a stationary condition until that device has been reset and the start device has subsequently been actuated. Where more than one emergency stop device is provided, means shall be incorporated to show which device has been actuated.
>
> The initiation of the emergency stop function shall not create a hazardous condition, e.g. dangerous discharge of conveyed material.
>
> The height of the emergency stop device shall be between 0,6 m and 1,7 m [≈24 to 67 in.] from the surface on which the operator stands.

In a later section, 5.7.2.9 Pull-cord operated emergency stop switch, *EN 620* specifies:

> The arrangement of pull-cord operated emergency stop switches shall be such that their associated switching device(s) will operate if the operating cord is pulled in any direction or if the cord breaks. Pull-cord switches shall also be designed so that the operating failure of any one spring will cause its associated switching device(s) to operate (i.e. not cause a failure to danger).
>
> The pull cord stop switch shall be actuated by the application of a horizontal force to the pull-cord of less than 125 N [≈28 lb_f], at a point midway between two support rings and perpendicular to the cord. The sideways cord movement (between the rest position and the actuation position) shall be less than 300 mm [≈12 in.].
>
> The movement of the operating cord and the force to operate the switch could be affected by the design of the cord supports and the distance between them. It shall therefore be ensured that the cord is free to move through the supports, particularly at changes of direction, without becoming disengaged from them.
>
> Only cords which are free from kinks and of a type unlikely to kink in service, shall be selected for use. The maximum length and other details shall be in accordance with the pull cord switch supplier's recommendations (e.g. protection of support rings and pulleys, prevention of freezing, changes in length due to temperature changes, etc.).

The requirements for conveyor-safety switches are also found in the following European Union standards:

> *ISO 13849*
> *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*
>
> *DIN EN ISO 13850*
> *Safety of machinery – Emergency stop – Principles for design*

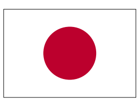
DIN EN 60204-1
Safety of machinery – Electrical equipment of machines – Part 1: General requirements

DIN 60947-5-1
Control-Circuit Devices and Switching Elements, Electromechanical Control Circuit Devices

India

Indian standard *IS 7155-2.1986 Code of recommended practice for conveyor safety, Part 2: General safety requirements* has the following instructions in 3.2.12.2 Pull Cords:

> The conveyor system shall be provided with stay-put type pull cord switches at suitable intervals along the conveyor so that any particular conveyor may be stopped from any position and in case any sequential operation is intended, the conveyor in sequence may also be stopped automatically.



Japan

Japanese Standards Association (JSA) offers standard *JIS B9703 (2011) Safety of machinery – Emergency stop – Principles for design*. This standard includes:

> 4.4.3 The emergency stop device shall apply the principle of direct opening action with mechanical latching. Electrical emergency stop devices shall be in accordance with *JIS C 8201-5-5*.
>
> 4.4.4 In the case of failure in the emergency stop device (including sustaining function), generation of the stop command shall have priority over the sustaining function. Resetting (e.g. disengaging) of the emergency stop shall only be possible as the result of a manual action at the location where the emergency stop was activated.

Section 4.5 Use of wires or ropes as actuators includes the following instructions:

> 4.5.1 When wires or ropes are used as the actuators of emergency stop devices, they shall be designed and positioned for ease of use. For this purpose, consideration shall be given to
>
> — the amount of deflection necessary for generating the emergency stop command,
>
> — the maximum deflection possible,
>
> — the minimum clearance between the wire or the rope and the nearest object in the vicinity,
>
> — making wires or ropes visible for the operators (e.g. by use of marker flags), and
>
> — the force to be applied, and its direction in relation to the wire or rope, to actuate the emergency stop device.
>
> NOTE: When it is likely that actuation will be attempted by pulling the wire along its axis, it is necessary to ensure that pulling the wire in either direction will generate the emergency stop command.

4.5.2 Measures shall be implemented to avoid hazards caused by breakage or disengagement of the wire or rope (see 4.4.4).

South Africa

The Mine Health and Safety Act 29 of 1996 mandates in section 8.9(1)(c) that an employer must ensure:

> The driving machinery of the conveyor belt installation can be stopped by any person from any point, along its length where access to the belt is possible.

While not specifically identified like the start-up warning alarm in *Regulation 8.9(1)(f)* and the method to prevent takeup movement during maintenance or cleaning in *Regulation 8.9(1)(g)*, it seems obvious that pull-rope safety switches would be included in the requirement in *Regulation 8.9(9)* that "any other safety devices relating to the conveyor belt installation" undergo weekly testing.

The 2016 edition of the Conveyor Manufacturers Association of SA Limited (CMA) guideline *Safety Around Belt Conveyors* offers the following recommendations:

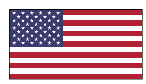
> 5.8 Pull-cord Stations
>
> Pull-cord stations are distributed stop switches with latching attachments. Pull-cord or pull-wire switches are required on all conveyors.
>
> Where conveyors are able to be accessed from both sides, the pull-switches must be located on both sides of the conveyor. Ingenious crossover systems have been developed to allow the use of pull-cord switches on both sides of the conveyor while utilising only one control system.
>
> Pull-switches are located along the conveyor at intervals not exceeding the dimensions as specified by the pull key manufacturer in conjunction with the risk assessments findings as legislated. The units are interconnected with a pull-wire and pull wires shall terminate at a live end.
>
> An operator activates the switch by pulling the pull-cord until the switch trips, interrupting power to the conveyor and usually raising a visual indicator flag. The switch remains tripped until reset manually at the switch location. The belt does not restart on reset of the pull-cord for safety reasons.
>
> Tripping of the pull-cord is a controlled stop, and shall not be considered a lock out of the conveyor power source, unless the units are specifically so designed. It is important to note that pull-wires are not substitutes for guards.
>
> Pull-wires must be installed in such a way that they are clearly visible and readily accessible from all areas that provide access to the conveyor.

['Pull key' is sometimes used in South Africa to refer to what in other locations (and this volume) are called pull-rope emergency stop switches. – Ed.]

Earlier versions of the CMA guideline contained more precise specification for the pull-rope switch system. The 2013 edition included the following:

> The pull force required to operate the switch shall not exceed 70 N [≈15.5 lb_f] when applied at mid span between supports, with a movement of not more than 300 mm [≈12 in.] when applied at right angles to the wire and must not exceed 270 N [≈60.5 lb_f] when pulled in-line.
>
> The pull-wire supports shall not exceed 6,0 metres [≈19.5 ft] (Australian Standard *AS1755* of 2000) irrespective of the distance between switch locations.

[While *AS1755* has been superseded by *AS/NZS 4024.3610*, the "6,0 metres [≈19.5 ft]" spacing requirement remains the same – Ed.]



United States

One conveyor emergency-stop standard often referenced in the United States is *American Society of Mechanical Engineers (ASME) B20.1-2015 Safety Standard for Conveyors and Related Equipment*, which contains the following requirements:

Section 5.11.2 Control Station

> (c) Remotely and automatically controlled conveyors and conveyors where operator stations are not manned or are beyond voice or visual contact from drive areas, loading areas, transfer points, and other potentially hazardous locations on the conveyor path not guarded by location, position, or guards shall be furnished with emergency stop buttons, pull cords, limit switches, or similar emergency stop devices.
>
> (1) All such emergency stop devices shall be easily identifiable in the immediate vicinity of such locations unless guarded by location, position, or guards. Where the design, function, and operation of such

conveyor clearly is not hazardous to personnel, an emergency stop device is not required.

(2) The emergency stop device shall act directly on the control of the conveyor concerned and not depend on the stopping of any other equipment. The emergency stop devices shall be installed so that they cannot be overridden from other locations.

Section 5.11.3 Safety Devices

All safety devices, including wiring of electrical safety devices, shall be arranged to operate such that a power failure or failure of the device itself will not result in a hazardous condition.

Section 5.11.4 Emergency Stops and Restarts

Conveyor controls shall be so arranged that, in case of an emergency stop, manual reset or start at the location where the emergency stop was initiated shall be required for the conveyor(s) and associated equipment to resume operation.

Before restarting a conveyor that has been stopped because of an emergency, an inspection of the conveyor shall be made and cause of the stoppage determined.

Section 5.12 Operation

(b) Where safety is dependent upon stopping or starting devices or both, they shall be kept free of obstructions to permit ready access.

Occupational Safety and Health Administration (OSHA) regulations in *29 CFR 1926.555 (a)* require:

(1) Means for stopping the motor or engine shall be provided at the operator's station. Conveyor systems shall be equipped with an audible warning signal to be sounded immediately before starting up the conveyor.

(2) If the operator's station is at a remote point, similar provisions for stopping the motor or engine shall be provided at the motor or engine location.

(3) Emergency stop switches shall be arranged so that the conveyor cannot be started again until the actuating stop switch has been reset to running or "on" position.

MSHA *Regulation 30 CFR 56/57.14109 Unguarded conveyors with adjacent travelways* states that these conveyors must have either:

> ... emergency stop devices which are located so that a person falling on or against the conveyor can readily deactivate the conveyor drive motor; or railings which are positioned to prevent a person from falling on or against the conveyor.

MSHA obviously expects the device would be located along the portion of the unguarded conveyor that is adjacent to a travelway and that a miner would be able to readily reach the emergency-stop device to activate it.

Additional MSHA guidance, presented in the 2010 guide to compliance presentation G*uarding Conveyor Belts at Metal & Nonmetal Mines*, offered the following:

> The positioning of an emergency stop cord is performance-based. Emergency stop devices need not run the entire length of the travelway, just the unguarded portion of the conveyor. The key provision is that persons can use it to READILY DEACTIVATE the conveyor.
>
> The emergency stop device does not have to be positioned so that a falling person automatically deactivates the conveyor.

MSHA considers control switches or devices to be electric equipment under *30 CFR section 77.502*, and so they must be "frequently examined, tested, and properly maintained by a qualified person to assure safe operating conditions." This inspection must be conducted on a monthly basis as mandated by *MSHA Program Policy Letter P12-V-02*. Although MSHA does not require inspections and tests be recorded

2

during the monthly examinations of electric equipment, a record of defective switches and arms must be kept.

BEST PRACTICES

- If workers can access a conveyor in operation, it must be equipped with an emergency shutdown device along the full length of the conveyor, including around terminal pulleys, takeups, and any auxiliary equipment such as scales, metal detectors, samplers, and magnets.
- The contacts used for emergency stop should be normally closed and directly actuated by a mechanical latching means.
- If the cord or tensioning spring breaks, the switch must open.
- A horizontal force of less than 125 N [≈28 lb_f], when applied midway between two support rings and perpendicularly to the cable, must be sufficient to activate the emergency switch.
- The cable(s) should be spring tensioned to reduce cable sag, and the lateral movement required to actuate the switch should be no more than 300 millimeters [≈12 in.].
- Distance between switches should not exceed 50 meters [≈164 ft], and the distance between support rings, pulleys, or guides should not be more than 6 meters [≈19.5 ft], or the manufacturer's recommendations if less.
- The cable should be routed within 1 meter [≈39 in.] of nip points or other hazards accessible to workers from walkways, platforms, or surfaces where workers would normally be walking or working.
- The pull ropes should be mounted at the proper height. The most detailed instructions are provided in *AS/NZS 4024.3610:2015*, where it specifies the ropes should be installed between 900 millimeters [≈35.5 in.] and 1,500 millimeters [≈60 in.] above the floor. (**Figure 6.12.**) If the conveyor's nip points are located higher than 1,500 millimeters [≈60 in.] above the working or walking level, the pull rope should be located below the nip points.
- The pull rope should be run so it has proper clearance along its length. This will allow a worker to grab and pull the wire when reaching around nearby nip points, guards, and other obstructions. At least 50 millimeters [≈2 in.] clearance on all sides of the rope is recommended.

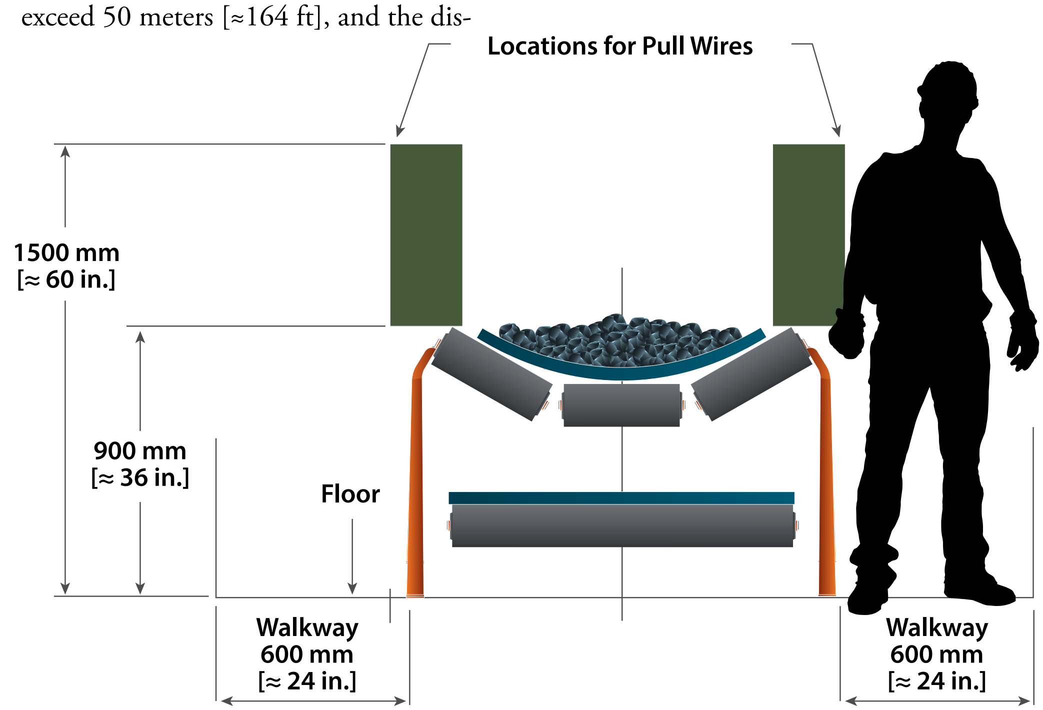


Figure 6.12.

Best practices for emergency-stop switches include mounting the pull ropes at a proper height.

- The switch enclosure should be IP 66 (NEMA 4 or 4X) or higher based on the environmental conditions and bulk-material hazards.
- The switch body should be yellow; the activation lever, shaft, or signal flag should be red.
- The cable should be a stranded wire rope of at least 1,250 Neutons [≈281 lb_f] working strength.
- The cable ends should be double clamped with properly applied cable clamps compatible in size and rating for the application.
- The cable should be sheathed to prevent injuries from protruding wires.
- The sheath should be a distinctive safety color, which is distinct from the color of the conveyor and guards. Red is suggested.
- Each switch should be test actuated on a running conveyor at least monthly. Associated cables, clamps, and guides must be examined monthly and maintained by a qualified person to assure safe operating conditions. Results of the tests, whether pass or fail, should be documented.

CLOSING THOUGHTS
The Role for Pull-Rope Stop Switches

While pull-rope emergency-stop switches are a required and valuable member to a plant's conveyor safety program, it must be noted that they are not a panacea or an end-all for safety problems. Workers who must work on or around belt conveyors cannot rely on pull-rope emergency-stop switches as a means to preserve life. Other tactics must be employed to improve belt conveyor safety.

Pull-rope switches possess certain limitations, which by the nature of the switch's design and application cannot be overcome. While no one would argue for the removal of these systems, it is wrong—perhaps dead wrong—to rely on them to save workers' limbs and lives.

It is also important to remember that the emergency-stop function shall not be applied for use as a substitute for safeguarding measures, but should be designed as a backup measure. All regulations and standards point out that emergency pull-cord switches are not a substitute for guarding. ⚠

Chapter 7 Backstops, Holdbacks, and Arrestors

INTRODUCTION

A conveyor belt is much like a large rubber band stretched between the pulleys, and this stretching can be substantial. Different belts stretch at different rates, with specifications allowing as much as four percent while in operation. Most fabric belts currently run with a stretch of one percent.

Much like a stretched rubber band, a conveyor belt has potential energy that if suddenly released—by a belt breakage or just a change in the forces keeping it in place—can also release violent forces. These forces can injure workers by pulling them into structural components or by releasing large quantities of cargo. These forces need to be controlled to reduce the associated risks.

The Importance, and the Risk, of Tension

Even when a conveyor drive is properly locked out and tagged out, the conveyor's belt is subject to significant forces applied as the result of stored belt tension. The amount of tension is based on the belt length, width, and incline; the weight of the material cargo; and the drive power applied to the belt. Much of a belt's tension comes from the conveyor drive mechanism, which moves the belt, and from the takeup system, which is used to tighten the belt so the drive mechanism can move the belt without slippage.

Most belt conveyors have the drive located at the discharge or head end of the belt conveyor. On these systems, the highest tension is located at the point where the belt is against the drive pulley. Directly after the drive pulley, the belt tension is considerably lower. Basically, this is because the belt and load are pulled toward the drive, whereas after the drive, the empty belt is pushed.

On a head-driven conveyor, the tension on the belt is highest just before the belt leaves the drive pulley, which in this case is the head end. The lower-tension areas of the belt are located on the return side of the belt. (**Figure 7.1.**)

When the driven pulley is located at the tail end of the conveyor, the lower-tension areas of the belt then move to the upper side of the belt system, with the lowest point immediately after the belt leaves the pulley. The highest-tension area of the belt is still just before the belt leaves the drive pulley.

The same principles hold true for a belt on which the drive is located in the center of the belt. Again, the highest tension is located just before the belt leaves the drive pulley. After the belt leaves the drive pulley, the tension drops drastically. As the belt travels toward the drive pulley again, the tension increases until it passes through the drive pulley and relaxes.

The location of the takeup mechanism and the place(s) where the belt receives its cargo also affect the areas where the belt is under the most tension.

It must be remembered that 'low tension' does not mean 'no tension.' Substantial stored energy may be present even in the lower-tension areas of the belt.

The Storage of Energy

Conveyors are high-inertia machines—they have a considerable amount of rotating and moving mass—with large amounts of kinetic energy (energy of motion) when in motion, and they can contain large amounts of potential energy (stored energy) when stopped. Both concepts are fundamental to understanding the design and operation of a conveyor.

Kinetic energy is the energy of motion, which is defined by Newton's Second Law: $F = m \times a$ (force = mass × acceleration). Another form of the equation is $F = ½ m \times v^2$ (force = ½ mass × velocity squared). The danger of energy of motion (kinetic energy) is more obvious than that of energy stored in a stopped system.

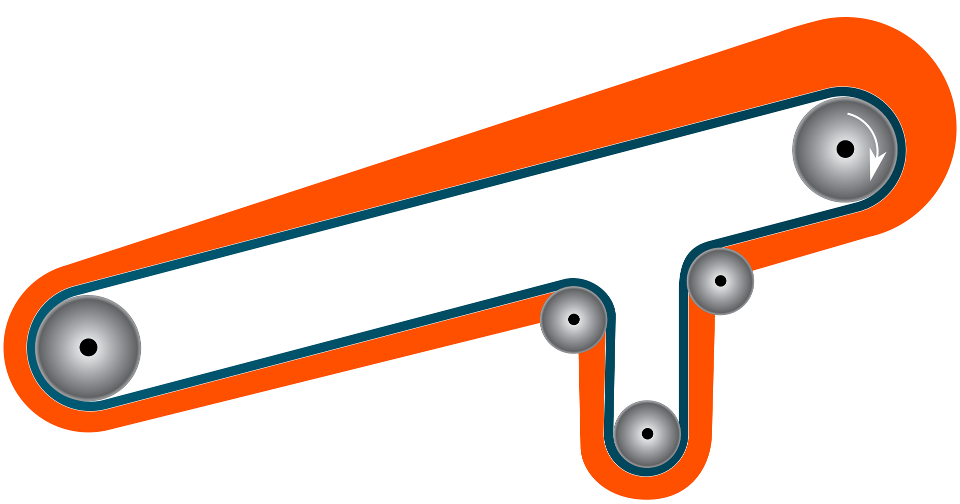


Figure 7.1.

The thickness of the orange color on this drawing indicates the proportional amount of tension on the belt at various points of a head-pulley driven conveyor.

Potential energy is mechanical energy that a body has by virtue of its position and mass. [In this book, we use the terms weight and mass interchangeably.] Potential energy is defined as $F = m \times h$ (force = mass × drop height). A special case of potential energy is elastic energy, such as the energy stored when the belt is stretched or when a spring is compressed. Elastic energy can be defined as $F = ½\ k \times x^2$ (force = ½ spring constant × stretch squared).

Stored energy and elastic energy present different hazards when talking about belt conveyors. Both represent forms of potential energy in a conveyor system; however, they arise from different sources with different probabilities and levels of severity for causing injury and property damage.

On belt conveyors, potential energy represents the forces that might result from any (or all) of the following:

- Weight of the belt and cargo on an incline/decline and the effective distance it could travel.
- Weight of the counterweight and distance it could fall.
- Weight of a lump or broken component and the distance it could fall from a belt or within a chute.
- Stretching of the belting.

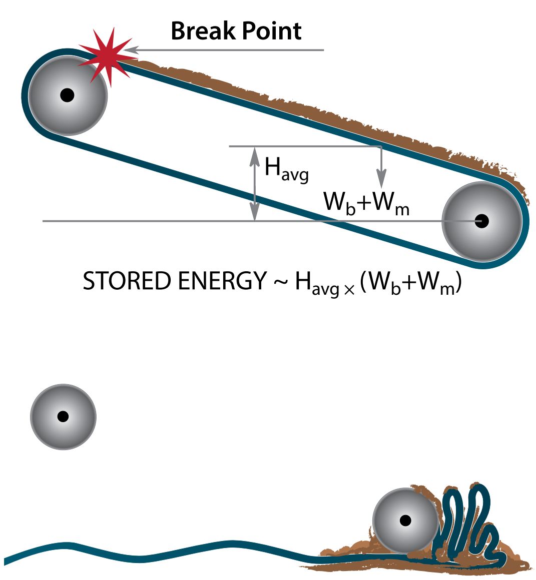


Figure 7.2.

***Top:** When a belt or splice fails, it breaks at the area of highest tension, typically at the highest end of the conveyor.*

***Bottom:** After it suffers a failure, the belt will fall from the head pulley, dropping the belt and cargo to the bottom of the conveyor.*

Generally, sources of potential energy are easy to identify. The most obvious is the takeup weight. However, simply lifting the takeup weight is not enough to put a conveyor system that has jammed into a zero-energy state. A less obvious source of potential energy is the buildup inside chutes, which can fall suddenly, damaging the receiving conveyor or injuring a worker cleaning inside the chute. Less frequent, but just as dangerous, are broken or worn components such as wear liners and return idlers that come loose and fall.

A horizontal belt, loaded or unloaded, will have less potential for release of stored energy, as there is little or no available fall height for the load or the empty belt. Empty inclined or declined belts also have very little potential for release of stored energy, unless they are cut in two or the drive train fails. That is because the lengths of the carrying run and return run are more or less the same, canceling each other's potential energy, and the rolling resistance of the idler and pulley bearings are generally enough to stop the belt from moving downhill.

A loaded inclined or declined belt presents a much more serious concern for the release of stored energy. Generally, the area of highest belt tension is at the highest end of the conveyor or at the drive. If the belt or splice fails, it usually fails in this location. On an inclined belt, this would be the discharge end of the conveyor; on a declined belt, it would be the loading end. When a loaded belt breaks, the stored energy is approximately equal to the weight of the material (W_m) on the belt plus the weight of the belt (W_b) times the average vertical displacement distance (H_{avg}). The belt and load begin to move due to the acceleration of gravity, quickly overcoming idler-bearing resistance, and the whole belt with all the cargo can end up at the bottom of the conveyor, tearing out idlers and structure as it accelerates. (**Figure 7.2.**) The end result is often catastrophic in terms of property damage and, if workers are present, serious or fatal injuries.

The Risks of Stored Energy

Elastic energy can be stored or trapped in a conveyor when high tension arises in a portion of a belt while another section remains at a lower tension, as when the belt is stopped or blocked. The takeup weight provides the minimum tension required for the motor to transfer the required torque to the pulley, which in turn rotates the head pulley. When an event stops the conveyor, whether from an emergency stop command or from an obstruction, there is still tension stored in the belt. Because of the unlimited number of loading conditions, belt paths, and possible locations of a jam, it is very difficult to predict which way the belt will move when the jam is resolved. Even if the conveyor is equipped with a holdback, there can be a significant unbalance of tensions in the belt. If there is no holdback, the conveyor will tend to distribute the tension equally around the path based on the takeup weight. However, if the belt is loaded fully—or even partially—or if the belt is long enough, the takeup may not be able to equalize tensions throughout the system.

A typical jam situation in which a rock jams the belt at the tail pulley and the motor eventually trips out is shown in **Figure 7.3**. Because the motor is capable of supplying peak torque higher than what is needed for the running torque of the system, the belt can be stretched beyond normal, storing vast amounts of elastic energy. If the belt has a one percent elastic stretch rating at the design tension, this over-tension situation may induce one percent or two percent stretch. Some fabric belts have an elastic stretch rating of up to three percent. If the belt is 200 meters [≈660 ft] tape length (total amount of belt on the conveyor), the belt can move up to three percent of 200 meters—or 6 meters [≈20 ft]—when the blockage is removed. Six meters is more than enough to pull a worker through any of the pulleys or idlers on the system and result in a fatal accident. This happens several times a year around the world and is avoidable.

A stalled conveyor can move in unexpected directions. A typical maintenance response would be to lift the takeup weight and then remove the rock from the tail pulley, given the circumstances shown in **Figure 7.3**. When the rock is removed, the belt will contract and release the stored elastic energy. In this example, the takeup pulley will move upward, because the takeup weight has been neutralized, causing the belt to play out in both directions—toward the head and tail pulleys. At the head, the backstop and drive will probably prevent the head pulley from rotating, and the belt will cause the tail pulley to rotate as the belt contracts.

The tail pulley is not constrained from rotating and will most likely rotate counterclockwise.

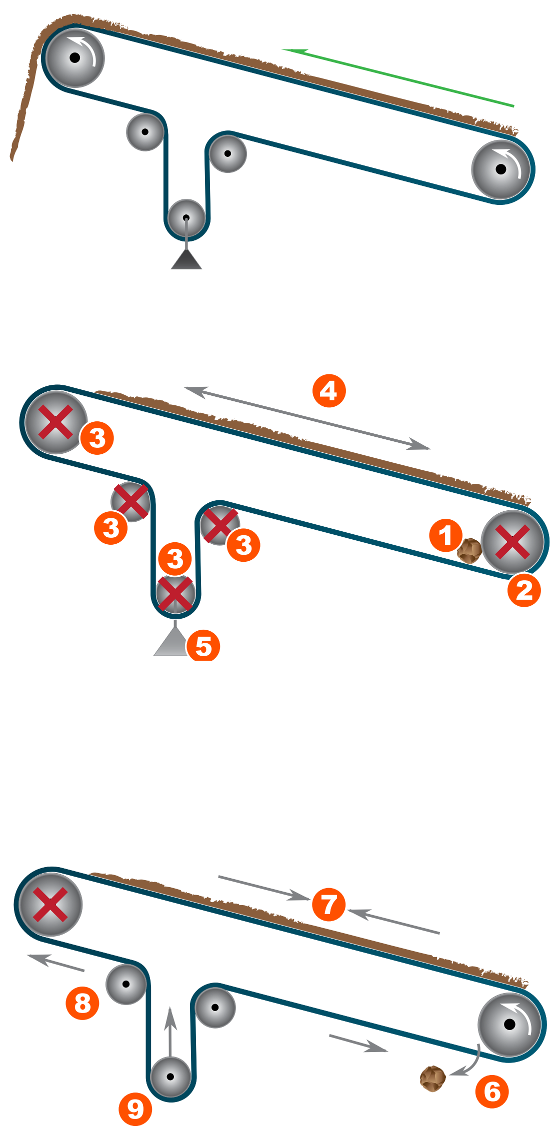


Figure 7.3.

***Top:** Conveyor in normal operation.*

***Center:** Rock entrapment sequence.*

1. *Rock trapped in tail pulley.*
2. *Tail pulley stops rotating.*
3. *Motor stalls and all pulleys stop rotating.*
4. *Belt stretches.*
5. *Takeup weight lifted to remove rock.*

Bottom:

6. *Rock removed and pulley rotates.*
7. *Belt contracts.*
8. *Belt moves across pulleys.*
9. *Takeup rises.*

Removal of the obstruction without first releasing the tension in the upper belt will result in the upper belt rapidly pulling the lower belt around the tail pulley with great force. Because of the large mass involved, significant energy of motion is created. Even with the belt locked out, this poses a great danger to any worker who had just removed the obstruction without tension-blocking mechanisms in place.

Even though the maintenance workers thought the system was dead and could not move the belt, the bend pulleys, idlers, and tail pulley may rotate. The equation for elastic energy indicates that this stored energy will be released and turned into energy of motion very quickly, trapping anybody working in close proximity to any freely rotating pulley or idler.

2

More than Lockout / Tagout

Lockout / Tagout practices do not provide enough security against accidents without adding Blockout and Testout. To minimize a hazard from energy stored in the system, the belt should be blocked at all potential sources of tension addition or subtraction to the system before a jam is removed. (**Figure 7.4.**) If in doubt, block everything to prevent injuries and avoid further equipment damage. (**See Chapter 23 Working Safely Around Conveyors.**)

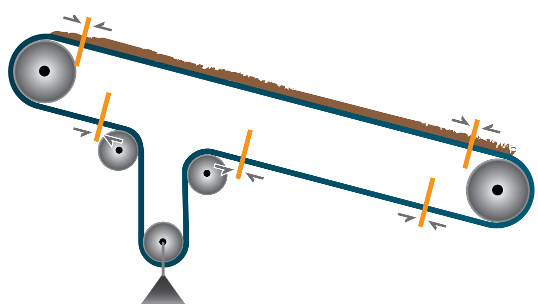


Figure 7.4.

To minimize hazards, the belt should be blocked at points where tension is added or subtracted to the system.

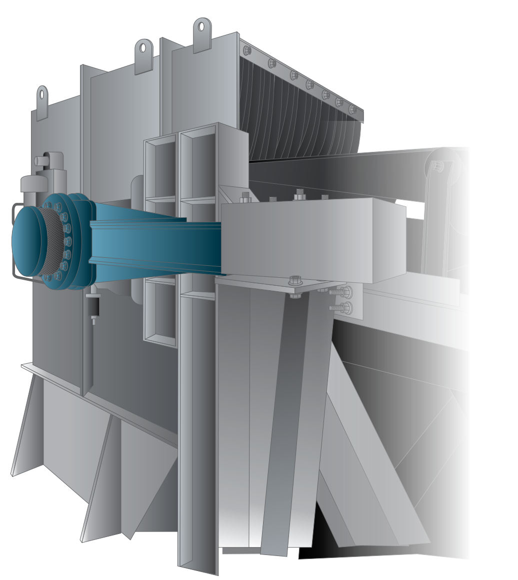


Figure 7.5.

An anti-rollback device—often referred to as a backstop or holdback—is typically installed on a conveyor's head pulley.

When a belt-conveyor system is designed, the tensions at different locations on the belt are studied in detail. This information should be readily available to maintenance personnel, so they can identify the sources and levels of tension in the system under different operating conditions whenever they work on a stopped belt.

Backstops or Brakes?

As a consequence of these hazards, inclined conveyors require an anti-runback device to prevent reverse movement of the belts. (**Figure 7.5.**) Such a device is referred to as a backstop or holdback. There is some disagreement on the use of these terms. In the United States, the Conveyor Equipment Manufacturers Association (CEMA) uses the terms backstop and holdback interchangeably. Others use holdback for low-speed shaft (pulley shaft) devices and backstop for high-speed shaft (in the gearbox) devices.

The seventh edition of CEMA's *Belt Conveyors for Bulk Materials* defines a backstop as:

> A unidirectional mechanical device that allows the conveyor to operate only in the desired direction. It permits free rotation of the drive pulley in the forward direction but automatically prevents rotation of the drive pulley in the opposite direction. This prevents the belt reversing and the material rolling back down an incline when the motor is not energized or other failures occur. Actuation is automatic and inherent to these mechanical devices so control is not an issue.

Though backstops are most likely to be found on inclined conveyors, they are also employed on flat, overland conveyors to avoid the unusually severe stresses at start-up when the loaded belt sags excessively between idlers.

Without a backstop, gravity can accelerate a loaded belt into a runaway condition, which can kill or injure personnel, damage or destroy drivetrain components, tear or rip expensive belting, or cause other considerable damage. A backstop is essentially a safety device which acts to prevent reversal, thereby protecting against any of the above from occurring as well as the massive cleanup of the likely material spillage.

Because backstops are unidirectional, brakes are used in combination with or instead of backstops.

Brakes are most often required when the system design requires controlling the starting and stopping tensions or on declined conveyors. Brakes are often used in combination with high-speed backstops or in place of backstops on downhill conveyors.

Brakes are normally installed on the driven pulley(s) (low speed) shafts. Brakes used on conveyors are usually of a mechanical disc or drum design and can serve as the primary anti-rollback device. Brakes used as safety devices are designed to be spring actuated and electromechanically released so that a power failure will result in brake actuation.

Brakes can also serve as a backup safety device, especially when high-speed backstops are used; brakes protect against mechanical failures in the gear reducer and coupling. Multiple brakes can be used in a system.

One advantage of a brake over a backstop is that it can be tested each time the conveyor is started and stopped.

The main concerns with conveyor braking systems are the wear of the friction surfaces and the variable friction coefficients as conditions change from weather or fugitive materials.

Preventing Rollback and Runaway

To prevent a reversing motion—often called rollback—of a loaded belt, inclined conveyors are typically built with a backstop mechanism. The function of the clutch is to permit rotation of the mechanism in one direction only, preventing any rotation in the reverse direction. In backstop applications, one race inside the clutch is fixed to a stationary member so that reverse rotation is not possible.

The seventh edition of CEMA's *Belt Conveyors for Bulk Materials* states:

> A shaft-mounted backstop (often called a holdback) is a mechanical accessory that allows a conveyor to operate only in the forward direction. It permits free rotation of the drive pulley in the forward direction but automatically prevents rotation of the drive pulley in the opposite direction.

Usually mounted directly on the drive pulley shaft and termed a low-speed backstop, this device permits free rotation of the drive pulley in the forward direction but automatically prevents rotation of the drive pulley in the opposite direction. Because these backstops permit travel of the conveyor only in the forward direction, they cannot be used on reversing conveyors or on downhill (regenerative) conveyors. In those cases a brake must be used.

Backstops can also be mounted on the high-speed shaft in the gear reduction train in combination with a brake on the low-speed (drive pulley) shaft. The advantage here is that the torque-holding requirements are much lower on the high-speed shaft. Quite often, a brake is required on longer conveyors for controlling the stopping of the conveyor under normal conditions. The disadvantage of this arrangement is that a failure in the power transmission train and pulley shaft, after the high-speed backstop, is not protected. However, when used with a brake, there is a redundant stopping capability.

In backstop applications, one race is always fixed to a stationary ground member. The function of the clutch is to permit rotation of the mechanism connected to the other race, in one direction only, and to prevent any rotation in the reverse direction at all times. Although the clutch normally overruns most of the time, it is referred to as a backstop in conveyors, gear reducers, and similar equipment because its function is to prevent reverse rotation.

Common designs for backstops include sprag and roller-style one-direction clutches. Both sprag and roller anti-runback devices work in a similar way, preventing the reverse motion by jamming something between inner and outer races. The 'something' in a roller unit is a number of rollers with a toothed internal runway. In a sprag unit, the jamming mechanism is a number of 'sprags'—figure-eight-shaped wedging pieces. (**Figure 7.6.**)

Low-speed backstops—so-called because they run at conveyor drive pulley speeds—are mounted directly to an extension of the drive pulley shaft on the opposite side from the drive. This location provides the most positive means of controlling belt reversal. It also simplifies any required service work on drive components.

Because of the one-way design, only one backstop is usually used on a conveyor; otherwise, they may work against each other.

Both designs are dependent on proper lubrication of the mechanical components. Periodic testing of a backstop is possible when the conveyor is stopped and the brake is released—if the gearbox gearing is designed for two-way motion. In some cases, the gearing does not allow reverse motion, so in order to test a low-speed backstop the gearbox must be uncoupled from the drive pulley shaft.

The clutch is braced against the conveyor structure using a torque arm. (**Figure 7.7.**) The torque arm is connected to the clutch and to the stationary conveyor structure by means of an arm installed into a slightly oversized stirrup. This allows the arm to move (slightly) when the belt reverses. When the loaded conveyor starts to move backwards, the anti-rollback action of the clutch is activated. The clutch rotates slightly against the force, allowing the torque arm to receive some of the load and transfer it to the conveyor structure. It is important to keep that arm free to move slightly within the stirrup, so the backstop can center itself to prevent pinching the bearings.

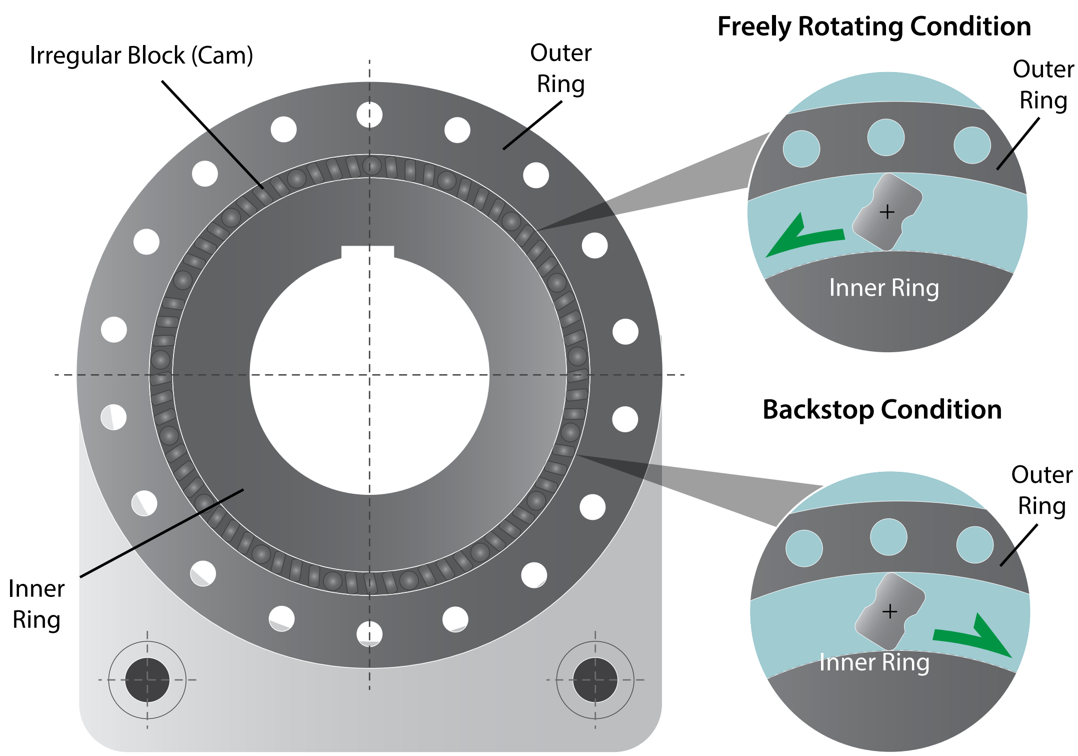


Figure 7.6.

When the rotation direction of the roller is reversed, the sprags in the bearing jam the races to prevent reverse motion.

Consequently, the bracket should be kept free of spilled material and other debris.

Because backstops are critical safety devices, their function should be tested monthly by stopping the conveyor under full load and observing any rollback. Their oil should be evaluated for metal fragments and remaining oil life at the same time the conveyor's gearbox oil is tested.

The operation of the backstop can result in unwanted energy being stored—as when the tail pulley is jammed due to seized bearings or material spillage. The danger is that the pulley (and hence the belt) will suddenly 'break loose' from the problem that was restricting movement, thereby releasing sudden and extreme forces that create a hazard. In addition to the risks created by the sudden and rapid belt motion and the probability of violent material discharge in unanticipated directions, there is the risk that the sudden release of energy can cause the drive system or other conveyor components to abruptly fail, with the chance of shrapnel and other hazards.

Consequently, safety precautions should be taken to release this stored energy prior to any inspection, cleaning, or maintenance. (**See Chapter 23 Working Safely Around Conveyors.**)

REGULATIONS AND STANDARDS

Many conveyor design standards and safety regulations specify that a backstop is required on inclined bulk-materials-handling conveyors. None of the standards specify a method or frequency for the testing of these devices, leaving those details to the manufacturer's recommendation.

Australia

In section 2.5.2 Anti-runaway device, the Australian/New Zealand standard *AS/ NZS 4024.3610:2015* specifies that devices that will automatically prevent runaway will be provided on any conveyor where the effects of gravity can cause the conveyor to run away.

The standard uses the phrase anti-runaway protective device to describe equipment that will stop an incline or decline conveyor, and so prevent uncontrolled motion in the event of a mechanical or electrical failure. The standard provides a list of the typical anti-runaway devices. These devices include but are not limited to brakes, holdbacks, eccentric pinch roller(s) on the conveyor return, ratchet-and-pawl or overrunning clutches on the shaft of the drive, self-locking worm gear reducers, and sprags or wedges in the space between inner and outer races.

It further states that if the failure of the anti-runaway device itself presents a hazard, two automatic devices should be installed, each of which would be sufficient to hold the load by itself. Each anti-runaway device shall be able to stop and hold 150 percent of the maximum load applied by the conveyor, including overload conditions. The standard mandates the devices be inspected for wear and operation, with appropriate periodic testing required.

A further disclaimer notes that the standard of withstanding 150 percent of anticipated load does not apply to the dynamic forces created in abnormal situations such as aborted conveyor starts and stops, although the standard does note the system backstops should be suitable for these forces at face value.

The standard suggests that the anti-runaway device be placed in the conveyor drive train in a location where failure is rare during the expected lifecycle of the conveyor. It further requires that if runaway protection is not installed directly on the conveyor's drive or

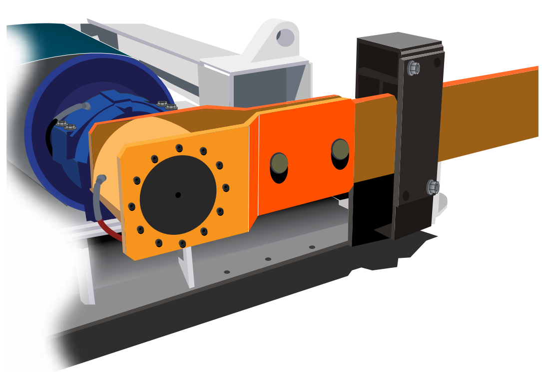


Figure 7.7.

A clutch braces a torque arm against a stirrup bracket to withstand the energy of the belt and prevent rollback.

driven pulley, the anti-runaway device should supply enough strength to compensate for the failure of any component in the drive train. The standard also notes that anti-runaway devices shall not be installed between a belt, chain drive, fluid coupling, or similar device and the drive motor.

Europe

European standard *EN 620 Continuous handling equipment and systems – Safety and EMC requirements for fixed belt conveyors for bulk materials* states in section 5.7.1 Measures for protection against failure of energy supply,

> If uncontrolled motion (especially inclined conveyors) may occur, conveyors shall be fitted with a means to stop and prevent further motion, which shall operate whenever the energy supply fails, e.g. a brake or other similar device.

Further, the design standard *DIN 22101 Continuous conveyors – Belt conveyors for loose bulk materials – Basis for calculation and dimensioning*, section 7.3.2 Stopping and holding states:

> The operation of belt conveyor installations generally requires the provision of braking equipment to stop the moving masses, and/or holding devices to hold inclined installations under load.

India

Indian standard *IS 11592-2000 Selection and Design of Belt Conveyors – Code of Practice*, section 8.11 Coasting spells out the performance requirements in three points:

- 8.11.2.1 Hold-back arrangement and/or brake shall be provided on conveyors which tend to reverse the direction of run when power is off or under very heavy overload.
- 8.11.2.2 Any conveyor requiring greater power to lift the load than the power required to move the belt and the load horizontally, shall be provided with hold-back or brake arrangement.
- 8.11.2.3 A regenerative downhill conveyor does not need a hold-back, but it shall be equipped with an automatic brake capable of bringing the fully loaded conveyor to rest within a reasonable time, when power is off.

South Africa

South Africa's *Mine Health and Safety Act 29 of 1996*, as revised in 2013, includes the following requirement in section 8.9(3):

> The employer must take reasonably practicable measures to prevent persons from being injured by material or mineral falling from a conveyor belt installation, which measures must include the fitting and use of one or more devices to prevent run-back or run-on; when such conveyor belt installation is stopped.

United States

A general requirement is stated in American Society of Mechanical Engineers standard *ASME B20.1-2015 Safety Standard for Conveyors and Related Equipment*, section 5.5 Backstops and Brakes:

> Antirunaway, brake, or backstop devices shall be provided on all incline, decline, or vertical conveyors, where the effect of gravity will allow uncontrolled lowering of the load and where this load will cause a hazard to personnel.

Occupational Health and Safety Administration (OSHA) regulations in *29 CFR 1926.555* refer back to *ANSI.B20-1957, Safety Code for Conveyors, Cableways, and Related Equipment* [which has since been updated as *ASME B20.2015 Safety Code for Conveyors and Related Equipment*].

To set a standard for United States coal mines, similar language is contained in Mine Safety and Health Administration's (MSHA) regulations in *30 CFR 77.1607 (dd)*, noting:

> Adequate backstops or brakes shall be installed on inclined-conveyor drive

> units to prevent conveyors from running in reverse if a hazard to personnel would be caused.

For United States metal and non-metal mines, MSHA regulations in *30 CFR 56.14113* and *57.14113* specify:

> Backstops or brakes shall be installed on drive units of inclined conveyors to prevent the conveyors from running in reverse, creating a hazard to persons.

Other Methods of Stopping Belt Reversal

There are other belt-stop safety devices that are considered optional accessories and which are not addressed by regulations. The seventh edition of CEMA's *Belt Conveyors for Bulk Materials* defines a conveyor belt stop as:

> ... any accessory that will limit the movement of or stop the backward festooning motion of the conveyor belt and load caused by a transverse rip or failed splice.

Belt stops—often called arrestors—are used to mitigate injury and damage. When an inclined belt fails, the failure usually occurs near the discharge pulley where the maximum tension—identified as T1 by conveyor engineers—has accumulated. (**Figure 7.8.**) The end of the loaded portion of the failed belt will accelerate in the reverse direction, usually causing damage in the surrounding area, and can be a danger to personnel in the vicinity. The end of the return side of the belt will also accelerate toward the tail of the conveyor, causing damage to return rollers and other components in the area.

An arrestor is a mechanical device that stops the motion of a rolling belt or a snapped (broken) belt. A belt stop or arrestor is installed prior to the point of maximum tension in the belt so that the ends of the belt may be caught or captured before they move very far down the system and cause injury or damage.

There are two common forms of arrestors. One consists of a method of stopping the backward rolling of a number of the rollers on the conveyor; the second is a sort of jaw that clamps on a runaway belt to stop its backward motion.

Anti-Rollback Idlers

One form of anti-rollback idlers uses single-direction bearings in the rollers. In these bearings, the inner race turns in the forward direction, for normal operation without adding friction. In the event of a belt reversal, when the roller begins to turn back, the inner race wedges itself against the shaft and the narrow part of the outer race profile, which in turn will stop the idler and the belt.

The anti-rollback idlers are available with either plastic (high-density polyethylene/HDPE) or 'steel can' rollers.

The drag produced by these rollers is a concern; to control this friction, the typical installation uses an alternating pattern of standard idlers and anti-rollback rollers.

Another issue is that the anti-rollback idlers can be installed backwards during maintenance replacement, adding tension and wearing the bottom cover of the belt.

Anti-rollback idler rollers are generally used on lighter conveyors such as package conveyors and, as a result, are not generally accepted in the bulk-materials-conveyor industry as a stand-alone safety system.

Belt Catchers

Another form of belt arrestor uses the pinching of a jaw mechanism to capture and hold a con-

Figure 7.8.

Failure of the belt or splice on an inclined conveyor can lead to the belt running downhill where it accumulates at the bottom of the conveyor.

2

veyor that is running away because of a failure in the belting, such as a splice that has come undone. These systems also go by the names of belt trap or belt catcher.

This style of arrestor is fitted with mechanical counterweights which close the 'jaw' to trap the belt. Under normal running conditions, the tension of the belt keeps the device open; in the event of a belt breakage, the tension from the belt is lost. This releases the counterweights, closing the arrestor's jaw to trap both the top and bottom sides of the belt and preventing them from running back down the incline.

Belt arrestors install on the stringers where most belt breakages occur. Typically, this is only on the carrying side, or below the head drive to catch both carry and return strands, so the ends remain in close proximity for splicing.

These systems are based on gravity, so they can function without any external (hydraulic, pneumatic, or electric) power supply, reducing maintenance issues and potential causes for failure.

BEST PRACTICES
Preventing Belt Reversal

- Require the system designer to run static and dynamic simulations of the system to identify the sources of tension and common situations where stored energy may present a hazard to the system or personnel. Common simulations involve starting, stopping, inclines loaded, declines loaded, and plugged chutes. Situations that are not normally simulated but should be, include broken belt/splice, jammed pulleys, active pulley failures, and low-tension pulley failures.
- Never depend on the backstop or brake to control unwanted motion of a belt when doing cleaning or maintenance, as the belt has the potential to move in either direction, depending on the balance of tensions at the point of the jam.
- Block the potential movement of the belt at each location where tension can be added actively (for example, drives, brakes, and takeups) and at each location where it can happen passively (for example, load on the belt, incline/decline flights, and failed components).
- Use belt clamps designed and manufactured for the proper rating and install them in accordance with the manufacturer's recommendations. Do not use homemade belt clamps.
- Provide anchors for belt clamps sufficient for the forces predicted from belt tension in the system design.
- Release belt clamps starting at the location of the suspected lowest tension and progress around the system, gradually releasing the tension around the system.
- Keep mechanisms and stirrups free of fugitive materials.

Backstops

- Backstops should be installed on inclined conveyors.
- Backstops should be tested monthly by stopping the conveyor under load and observing the backstop engagement.
- Backstop lubrication levels should be inspected monthly and lubricant quality tested every six months.
- The torque arm of the backstop must be kept clear of debris and fugitive material inside its bracket or stirrup. Make sure the installation of the backstop torque arm does not impede access to critical accessories, such as belt cleaners and bin-level detectors.
- Backstops should be tested monthly by stopping the conveyor under full load and overserving backstop engagement. The results of testing should be documented.

Brakes

- Brakes should be installed on conveyors using high-speed backstops as a secondary safety measure.

- Brakes are usually required on downhill (regenerative) conveyors.
- Brakes should be tested monthly by stopping the conveyor under full load and overserving belt motion. The results of testing should be documented.

Belt Stops

- Belt stops should be installed on inclined and declined conveyors in the area of highest belt tension.
- A belt stop should be considered if there is a sloped section of conveyor where a break in the belt would create a serious safety condition for personnel or a lengthy recovery and difficult repair circumstance.
- Belt stops should be tested monthly to ensure the tension sensing and clamping mechanisms are free to move their full range under no tension situations. The results of testing should be documented.

CLOSING THOUGHTS
Controlling a Reversal of Fortune

As we have seen, there are a number of ways to control unwanted belt motion. These belt-stopping mechanisms provide an improvement on safety for personnel, as well as a support for the efficiency of the conveyor system and the overall plant.

However, if workers are required to be on the conveyor or near pinch points on the conveyor, the belt must be physically restrained from moving under its own power even when locked out. ⚠

2

2

Chapter 8

Hoods and Covers

INTRODUCTION

In this chapter, the words 'hood' and 'cover' refer to accessory components used to protect a conveyor along its run from tail to discharge. The hood or cover is typically an arch of rigid sheeting, held in place by a hoop-like band. Typically, hoods or covers are used outside the loading or discharge chutes (transfer points). (**Figure 8.1.**)

In this volume, 'hood' and 'cover' are used interchangeably. References in this section are not to be confused with the cover(s) of belting, that is, the outside layer(s) of elastomer around the carcass of conveyor belting. Similarly, references in this section should not be confused with the 'hood' installed at the top of a 'hood and spoon' engineered chute to contain the material stream and direct it down to the 'spoon' at the bottom.

Protecting the Belt, Limiting Exposure to Weather

Conveyor hoods are installed on the stringers to span across the carrying run of the belt. (**Figure 8.2.**) They are used to keep dust in and weather out. Covers protect the belt, idlers, and material being conveyed from the sun, wind, snow, rain, and other damaging environmental conditions. On inclined conveyors, wet cargo and/or a wet belt creates the risk for material sliding down the incline, leading to damage to equipment and injury to personnel.

In the 7th edition of *Conveyors for Bulk Materials* from the Conveyor Equipment Manufacturers Association (CEMA), it is recommended that some form of "weather protection shall be installed whenever the cargo or return run must be protected from the elements," or "whenever the wind speed is frequently in excess of the speed that will create fugitive material or push the empty belt out of alignment."

Mounted on or attached to the conveyor's stringers, covers over the belt do not totally prevent dust emissions. No stringer-to-stringer conveyor hood will control the venting of air flow and airborne dust resulting from the transfer of bulk materials from a preceding transfer chute. The hoods protect the material on the conveyor from becoming entrained in prevailing (primarily cross-conveyor) wind currents and being carried off the conveying belt. Hoods also help prevent high winds from lifting an empty belt off the carrying idlers which can result in belt damage or the belt folding over on itself. If the primary concern is high winds lifting the belt, wind hoops or wind screens may be a cost-effective alternative.

Hoods can serve to prevent inadvertent access to the nip points between the carrying idlers and belt. (**Figure 8.3.**)

Other benefits of conveyor covers:

- Can reduce the release of idler and belt noise
- Can reduce contamination of the bulk-material cargo
- Can protect the cargo and conveyor from animals getting into the conveyor and the resulting contamination or product loss.

Designs and Features of Conveyor Hoods

Available from a number of commercial suppliers, conveyor hoods are typically formed as an arch above the top run of the conveyor and are installed from one stringer to the other. (**Figure 8.4.**)

Figure 8.1.

Hoods or covers are used to protect the conveyor and its cargo for long runs away from transfer points.

Figure 8.2.

By enclosing the conveyor from stringer to stringer, a conveyor cover protects the cargo from environmental conditions.

Figure 8.3.

Conveyor hoods can be supplemented with screens to keep workers away from moving components.

2

The Difference Between Gallery or Hood

Conveyor galleries are the long enclosed passages through which a belt conveyor will pass. These fully enclosed structures—almost tunnels or tubes—are used to protect an enclosed conveyor.

Galleries are structures that combine the structural support of the conveyor and protection from weather while providing an enclosure to reduce the release of fugitive materials and make cleaning easier or at least confined. A gallery is typically a structural steel frame covered with metal or plastic siding. It can also be made from large diameter steel tubes, reinforced concrete, or a combination of different construction methods. Typically, galleries span between towers in a conveyor system and result in completely enclosing the conveyor.

A gallery protects personnel, machinery, and the material conveyed from the weather. The *Goodyear Handbook of Conveyor & Elevator Belting* (commonly referred to as the *Red Handbook*) states, "Unless the climate is favorable, permanent conveyors usually require a gallery to protect the belt from strong winds and to protect men and material."

A gallery is usually of sufficient width so maintenance and inspection personnel can pass readily along at least one side. The best practice is to provide minimum space for maintenance on one side and a wider space on the other side for a safe travelway and for cleaning and maintenance. Galleries can be built with solid floors or open-grating floors depending on the necessity for confining fugitive materials for cleanup within the gallery or letting the fugitive material fall to the ground.

Galleries with solid floors prevent fugitive materials from falling, and so should be used if belt conveyors pass over protected lands or waterways.

As noted in the CEMA book *Belt Conveyors for Bulk Materials*:

> The designer of an enclosed gallery should consider the possibility that spillage or other materials may collect in the bottom of the tube, creating a large unintended weight that must be supported. Ventilation of the gallery may also be a design consideration.

Conveyor hoods, as they are open at the bottom, generally do not have this issue.

One benefit of a gallery is that it improves maintenance practices. As the *Red Handbook* noted, "Attention given a conveyor by workers exposed to rain and snow is not apt to be painstaking." Walking up the catwalk on an inclined conveyor in snow for maintenance or inspection is challenging; in harsh conditions, maintenance of outside conveyors will likely be abbreviated or cursory.

While galleries and hoods often serve a similar function, galleries are usually installed as the conveyor system is constructed. Hoods and covers can be installed during initial construction or added as an after-market fix. Hoods are commonly used on longer conveyors, such as long inclined or overland conveyors, where it would be impractical to construct a gallery due to cost or topography.

Typical conveyor gallery, interior view.

Typical conveyor gallery, exterior view.

Covers left off after maintenance can expose workers to hazards.

Hoods are obviously less expensive than galleries but generally offer less protection against weather. Hoods on the other hand, if maintained, offer greater safety than galleries unless nip-point guards are provided on the carrying run in the gallery.

Hooded conveyors and galleries should incorporate fire detection and fire protection systems. One disadvantage of hoods is that they are often left open or even removed after maintenance and cleaning and not replaced. While not replacing and properly fastening the hoods is a training and management issue, it is common. Improperly latched hoods can be caught by the wind and be damaged, making closing difficult or impossible. The design of the hood and fastening system can mitigate some of the tendencies to leave them open or off the conveyor.

Hoods that are damaged or simply not replaced should be a maintenance priority as they provide the multiple benefits of helping to control fugitive materials and serving as at least partial guards for conveyor nip points.

Typical forms are a 'full cover,' (180-degree arc), a 'three-quarter cover,' (135-degree arc) and the 'half' (90-degree arc) cover. (**Figure 8.5.**)

The 180-degree 'full' hood provides the maximum safety for personnel from moving parts. It also extends the wear-life of covered components such as idlers and the belt by protecting them from the rain and sun. This hood type is efficient and environmentally friendly, containing dust and reducing material loss due to high winds. This benefit is countered with the fact the belt is now more difficult to inspect and access.

The two designs with the shorter arcs provide less coverage, while allowing easier inspection and maintenance. With these partial hoods, the cover can be installed so the open side is tilted, either toward the side of the conveyor with the walkway (to facilitate inspection) or to better shield the belt from a prevailing wind.

There is a usually a gap between the top of the stringer and bottom edge of the cover. This gap can be closed by extending the hood below its mounting feet, generally at additional cost. Some suppliers offer optional side walls and spill trays to create a fully enclosed conveyor. (**Figure 8.6.**)

All types can be hinged so that an individual cover can be raised to offer better inspection or worker access to the belt and components. Hinges and latching mechanisms should be designed so the hood can be opened quickly, easily, and safely for inspecting components or viewing the material being conveyed. The hood should be designed to allow easy belt and idler maintenance; they must allow for ease of inspecting, greasing, repairing, or replacing of an individual roller or an entire idler set. The installation should provide a method to hold or prop the cover open so the cover is secure in the open position.

The hood system should be user-friendly, easy to install during construction, and easy to open/remove and close/replace for inspection and maintenance. It is best if these procedures can be performed without tools.

It is possible conveyor hoods will interfere with inspection and maintenance of conveyor idlers. Consequently, the hoods should be simple to open and latch closed or include inspection doors or windows.

They should be designed to be maintenance-free as much as possible, with corrosion-

Figure 8.4.

Conveyor covers provide protection from the elements while allowing inspection of conveyor components.

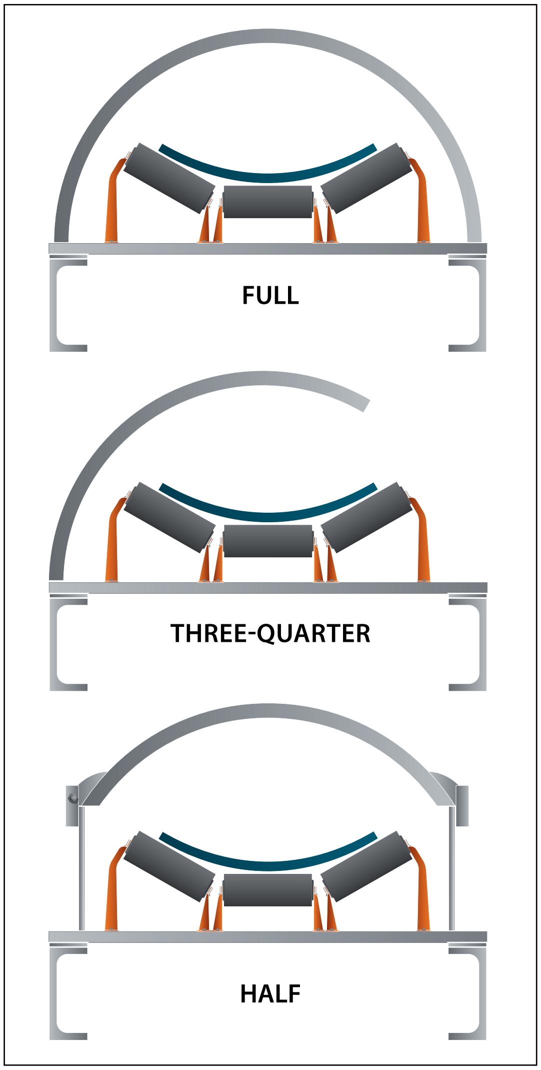


Figure 8.5.

Typical styles of conveyor covers include Full, Three-Quarter, and Half covers, which form 180-, 135-, and 90-degree arcs, respectively.

2

resistant materials and simple hinge and latch mechanisms. The hood should be weatherproof under a wide range of conditions. It should shed water away from the belt and the walkway and not trap water in the hinge or latch, as that will promote corrosion in the mechanism.

Adjacent hoods should overlap or have a joining strip to form a tight seal, to prevent them acting as a collector or funnel that allows rainwater to fall between and onto the belt.

Covers can be made in smooth or corrugated materials, in galvanized or painted steel, stainless steel, aluminum, fiberglass, or plastics. The choice of cover material should be matched to application conditions, to contain corrosive materials on the inside and withstand exposure on the outside. Construction should be robust enough to withstand both wind and snow loads.

Most hood assemblies come with heavy-duty corrosion-resistant mounting brackets that attach to the conveyor stringer, and with a retaining bar to hold the cover in an open position for maintenance.

Hoods are typically available to match standard belt widths. Custom sizes are generally available to meet specific requirements.

Cover assemblies are typically made to accommodate idler spacing from three feet [≈915 mm] to five feet [≈1,524 mm] on-center, with four feet [≈1,250 mm] spacing being standard. Most manufacturers can supply covers to fit convex or concave horizontal curves or covers can be field modified.

REGULATIONS AND STANDARDS

Only a few standards or regulations reference the use or design of conveyor hoods.

Many geographic regions may have standards for the wind load that structures—including conveyor hoods—should withstand.

BEST PRACTICES
Conveyor Hoods

There are no safety standards or specifications for the design or use of conveyor hoods or

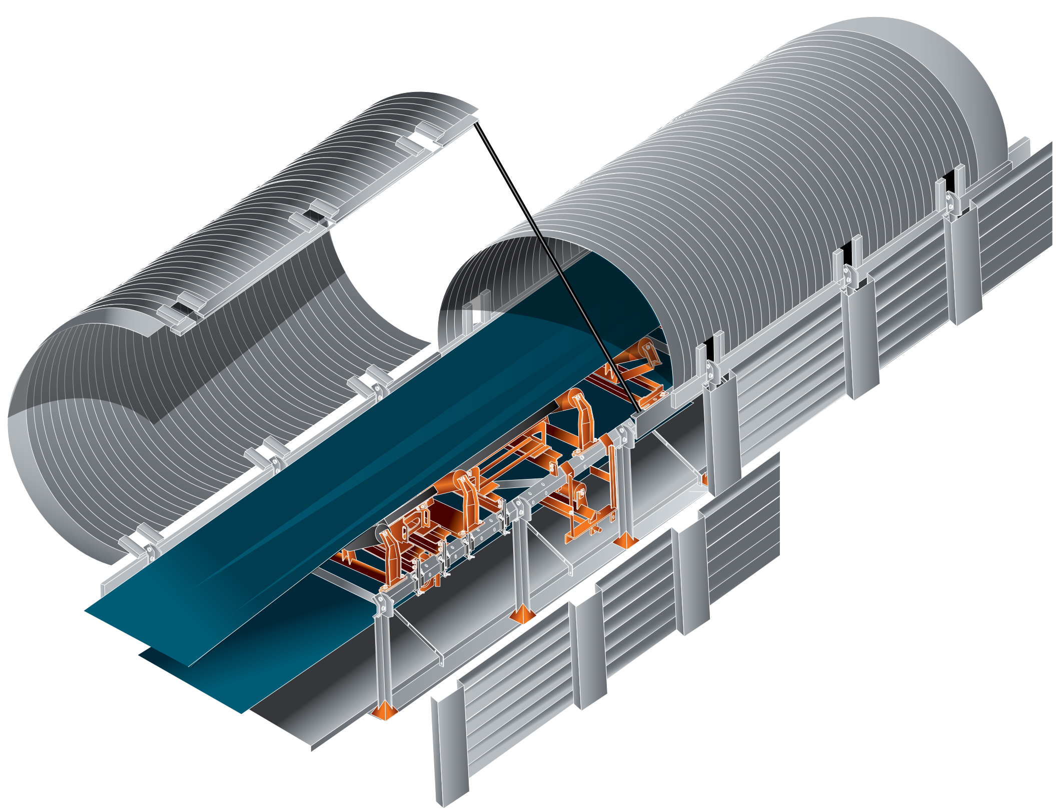


Figure 8.6.

Conveyor covers can be used with sidewalls to contain material and protect workers.

2

covers. However, a few safety-related points should be considered.

- The design and installation must be compatible with pull-rope stop switches and conveyor guards. In addition, the system must coexist with fire suppression systems, speed monitors, and other safety and control systems.
- The hood must not interfere with maintenance work or increase the risk of injury.
- Covers should be designed to shed water so rain and snow will fall away from the belt and from the walking surfaces.
- Whether open or closed, covers should be securely mounted so they will not blow off the structure when faced with high winds.
- Care should be taken when opening hoods in high winds as they can be easily caught in the wind, opening rapidly and throwing a worker off balance, or bending the cover back.
- The latching mechanism should be easy and safe to operate by one worker, and allow the hood to open while the conveyor is running without exposing workers to hazardous moving components.
- A hinged cover should provide a method to brace the cover open, holding it securely so it will not accidently close on a worker.
- The presence of covers may complicate the removal or reinstallation of other nearby components such as idlers.
- There may be some difficulty and risk in the removal or reinstallation of a cover itself, as well as with other nearby components such as idlers. Hood sections should be designed to stay within the common lifting limit of 23 kilograms [≈50 lb] or equipped with handles or handholds for lifting by two people. This is particularly true on conveyor belts wider than 1,000 millimeters [≈39.5 in.] where the weight of the cover will create added difficulty in handling.
- Hood edges should be deburred and corners rounded to reduce hazards to workers.

CLOSING THOUGHTS
Under the Hood

There are obviously mixed blessings with conveyor hoods; the operation gets reduced exposure of the conveyor and its cargo to climate conditions, at the cost of losing visibility of and access to the conveyor. These trade-offs are generally acceptable where environmental concerns must be addressed or when considering the safety of those who must work on or around the conveyor. ⚠

Chapter 9 Crossovers and Crossunders

INTRODUCTION
To Get to the Other Side

As noted in Chapter 2, a surprising number of accidents happen to personnel who are crossing over or under a belt conveyor.

These accidents occur in spite of the often-cited safety admonition 'do not climb on, over, or crawl under any conveyor.' But operational necessity will require that workers get from one side of a conveyor to the other, either to perform conveyor-related activities or merely to pass from one side of the plant to the other. To safely allow that passage, conveyor crossovers are installed. (**Figure 9.1.**)

The 7th Edition of the Conveyor Equipment Manufacturers Association (CEMA) book *Belt Conveyors for Bulk Materials* says:

> Crossovers or crossunders are used to allow personnel to safely cross conveyers at designated and approved locations when the physical layout does not pro-

vide safe and easy access from one side of a conveyor to another.

That reference continues:

> Crossovers and crossunders are also used where there is a need to control foot traffic for safety reasons, or on longer conveyors where there is temptation to take an unsafe short cut.

Avoiding the Temptation, Minimizing the Risk

Despite all the plant-issued safety warnings and prohibitions, there is a temptation for workers to take shortcuts and step over or crawl under moving conveyor belts—rather than go 'all the way' around to a place of safe passage or to wait until the belt is properly shut down.

In a section titled "Human Factor Considerations," the CEMA publication *Safety Best Practices Recommendation (CEMA SBP-001) Design and Safe Application of Conveyor Crossovers for Unit Handling Conveyors* (**See CEMA Offers Best Practices for Crossovers**) sums up this need for crossovers as follows:

> In operations areas where personnel are familiar with the conveying equipment,

Figure 9.1.

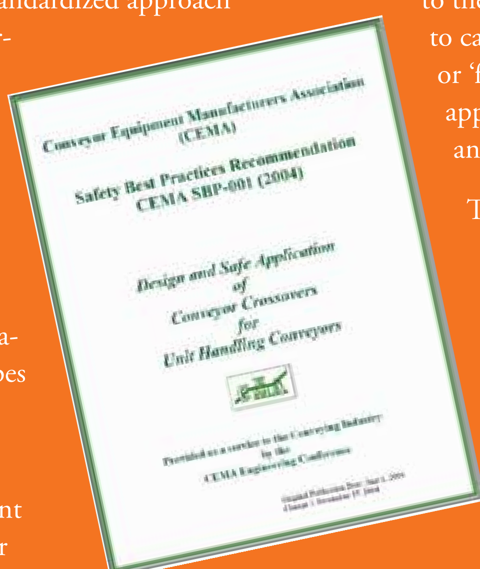
Conveyor crossovers are installed to allow safe passage from one side of the belt to the other.

2

CEMA Offers Best Practices for Crossovers

In 2004, CEMA in the United States published a design standard: *Safety Best Practices Recommendation for the Design and Safe Application of Conveyor Crossovers for Unit Handling Conveyors* (*CEMA SBP-001*).

This guideline offers an outline of a standardized approach to the structures provided to allow personnel to cross conveyor lines. Although originally published as a guide only for unit handling conveyors, it provides useful guidelines for the design of conveyor crossovers for bulk-materials-handling conveyors. The safe practices for design and application information in this publication are applicable for all conveyor types including bulk-handling conveyors.



The CEMA *Best Practices* publication categorizes crossovers into four different types, including crossovers at conveyor height (Types 1 and 2) and crossovers above the conveyor (Types 3 and 4). Ladder designs are Types 1 and 3; stairway designs are Types 2 and 4. The publication gives general guidelines for application and discusses comparative advantages and disadvantages of the various types of crossovers.

The CEMA *Best Practices* publication also provides general guidelines for application. These are based on accessibility to the general public, the need for pedestrians to carry items, and limitations in floor space or 'footprint.' The guidelines include a general application chart based on frequency of use and the step-to-step distance.

The publication also notes:

> Specific conditions will vary from application to application, as will the purposes and experience level of the personnel expected to use the crossovers. These varying conditions, purposes, and experiences will affect the selection of the type and design of the equipment provided in any given situation.

The CEMA *Safety Best Practices Recommendation for Conveyor Crossovers* is available as a free PDF download from the CEMA website, cemanet.org.

2

and their duties or routes of travel can require movement across conveyor paths, there is great potential for abuse of the most basic safety rules. Temptations for these personnel to cross running and/or temporarily stopped conveyors are very strong. Experience has shown that accidents are inevitable under these conditions. Continuous analysis of worker requirements for movement and access in the conveyor operating areas is necessary. Proper application of crossovers at the 'most needed' locations can go a long way towards promoting workplace safety when conditions would otherwise present the temptation to cross the conveyors in an unsafe manner.

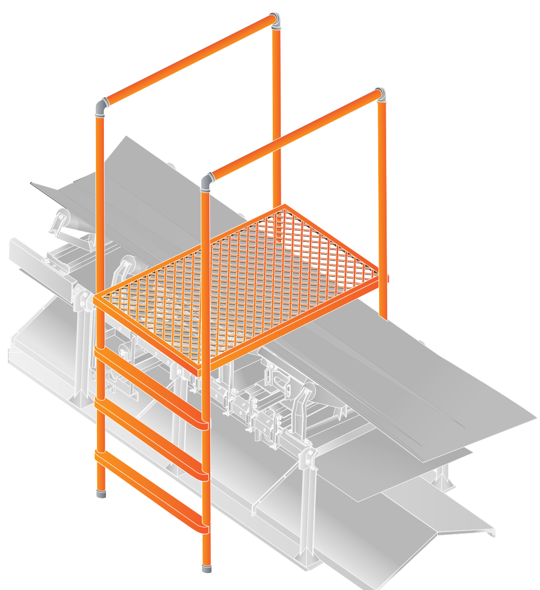


Figure 9.2.

One style of crossover combines one or more ladders with a walkway.

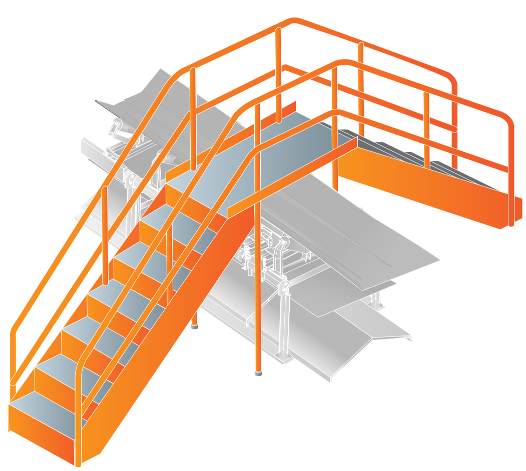


Figure 9.3.

A stair crossover is typically two stairs joined by a walkway with railings.

The State of Washington's conveyor safety standards, published in *WAC296-806-42032,* specify that a plant must:

> ... install a pedestrian overpass or underpass along the sides of long overland belt conveyors, where there is the most foot traffic.

This removes (or at least lowers) the temptation to cross a conveyor line because the distance to the next crossover is 'too far.'

In section 8.1.2.4 of its *Mandatory Code of Practice for the Safe Use of Conveyor Belt Installations for the Transportation of Minerals, Material or Personnel*, (Revision 2), De Beers Consolidated Mines' Venetia Mine in South Africa includes a practical (yet perhaps unattainable) goal: "There shall be sufficient cross over walkways to prevent people from taking short cuts."

It is human nature to take shortcuts. Installation of well-designed and well-placed crossing structures to overcome this human nature is an example of improving safety by design.

Crossovers in General

Conveyor crossovers are platforms that span the width of the conveyor belt. They provide a footpath or walkway above the belt and the conveyed material. Crossovers usually include ladders or steps to allow a worker to access the elevated walkway. They can be as simple or as complex and as elevated as required to provide a safe passage.

CEMA SBP-001 has defined two general types of crossovers:

> **Ladder Crossover** – A conveyor crossing device consisting of one or more ladders with support railings and, possibly, a platform that traverses the conveyor path. (**Figure 9.2.**)
>
> **Stair Crossover** – A crossing device, with a slope of less than 50 degrees, consisting of one or more stair step assemblies which may be joined together across the conveying surface by railings

or railings and a platform or walkway. (**Figure 9.3.**)

Another, perhaps hybrid, type is referred to in *CEMA SBP-001* as a Ship's Stair or Ship's Ladder. This is "a stairway equipped with treads and stair rails with a slope of 50 to 70 degrees."

The stair crossover is generally perceived as 'safer' and 'easier' for workers. But the choice of type for a given installation may be dependent on the available footprint; that is, if there is space to allow an installation of a stairway rather than a ladder.

Crossovers are also occasionally referred to as stiles.

Crossover Design and Construction

The choice of crossover for a given application will depend on the kind of use, the size of walkway or work platform needed, and the likelihood of needing to move or reconfigure the crossover. In addition, local codes and site-specific rules may govern the style, location, and use of crossovers and crossunders.

Crossovers come in many configurations and materials. Crossovers can be designed with straight-over access or H-shaped, L-shaped, U-shaped, or Z-shaped stair and platform configurations. (**Figure 9.4.**)

Crossovers made of welded steel are very durable and have high-weight capacities, but they are often difficult to move once installed due to their one-piece construction. Modular aluminum crossovers may not have the same weight capacities as welded steel crossovers, but they do have the advantage of being lighter in weight and modular in design. This means the modules can be taken apart and reconfigured to meet new needs or locations.

The 7th Edition of *CEMA's Belt Conveyor for Bulk Materials* reference book specifically notes:

> Appropriate guarding or other physical barriers surrounding a crossover or crossunder should be supplied according to code to protect personnel from moving conveyor components and spillage.

There are a number of suppliers of pre-engineered crossover systems with choices to fit most applications. It is imperative any systems selected are in compliance with local regulations including path width, elevation above the belt, construction methods, and engineering details.

Considerations for Crossover Engineering

When engineering a conveyor crossover, there are a number of aspects that must be considered.

Because a crossover allows workers to cross a conveyor belt, the load-bearing section of the crossover must be designed to withstand the load created by one or more human beings. In addition to the static load of personnel standing on it, the crossover structure must account for the additional dynamic load created when the people are moving. The design must also accommodate any environmental loads such as snow or wind and anticipated accumulations of fugitive materials. The design must also include a generous safety factor because human life is at stake.

This platform will be elevated above the belt and properly supported. If the steps or crossover platform is close enough to the moving belt or cargo, there is the potential that the worker is at risk of coming into contact with the hazard. The crossover surface must be posi-

Figure 9.4.

This single-ladder crossover bridges two conveyors while allowing workers to step off in between the two belts.

2

tioned high enough so that the belt and the largest pieces of cargo can pass under without interfering with the structure or persons using the crosswalk. If the steps or platform are close enough to the moving components, there is the potential that an appendage will come in contact with the moving part. Most operations eliminate the chance of accidental contact with the belt by raising the crossing platform far enough above the belt. This should eliminate the possibility that a worker will accidentally come in contact with a moving component. (**Figure 9.5.**)

In addition, the crossover should include well-designed and structurally sound rails and kick plates to keep persons on the crossover or the stairs to the crossing level from falling to the ground or onto a moving conveyor belt. Local standards will determine the height and construction materials of these rails.

Crossing Under a Belt

In facilities where—for whatever reason—a crossover cannot be safely or reasonably provided, workers may be required to cross under a belt. The need to pass under a belt poses increased risks to workers. The hazards of uncontrolled crossing beneath an operating conveyor include exposure to pinch points.

Alberta's *Occupational Health and Safety Code Explanation Guide* noted another hazard in Part 25 Tools, Equipment and Machinery, Subsection 373(1):

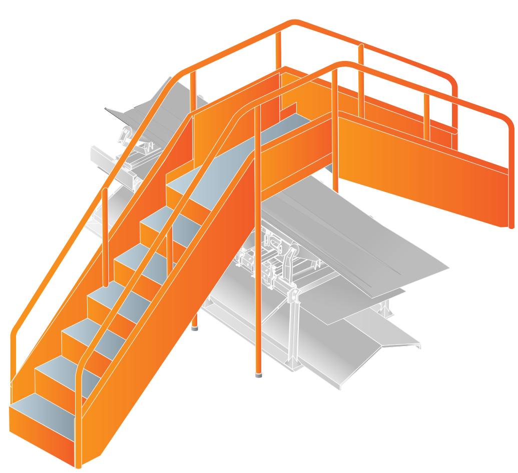


Figure 9.5.

A crossover should be far enough above the conveyor to eliminate the risk of a worker accidentally contacting the belt or a moving part.

> Workers crossing under a conveyor may be at risk of injury due to objects falling from the conveyor belt or getting caught in the moving parts of the conveyor belt. Workers must only cross under conveyor belts where they are protected from falling materials and moving parts.

Therefore, in areas where workers will pass under the belt, components should be guarded and the passageway equipped with nets, roofing, or other systems to prevent these hazardous exposures such as falling bulk material.

The 7th Edition of *CEMA's Belt Conveyors for Bulk Materials* says, "Use crossunders where exposure to a nip point or pinch point is not considered guarded by location." That is, where the hazards are closer than the minimum required distance, use an engineered structure, cover, or roof to protect the workers.

The Utah Administrative Code, in its *Occupational Safety and Health Rule R614-5. Materials Handling and Storage* – R614-5-2 Conveyors C. Walkways, Platforms, Balconies notes:

> Where workers must cross under a conveyor, crossunders shall be plainly marked as the only passageways. The passageway shall be covered to prevent contact with moving parts or material falling off the conveyor.

Similarly, in its *Mandatory Code of Practice for the Safe Use of Conveyor Belt Installations for the Transportation of Minerals, Material or Personnel*, (Revision 2), De Beers Consolidated Mines' Venetia Mine notes in section 8.1.2.1:

> In order to prevent inadvertent contact with moving parts of the conveyor belt installation, guarding shall be applied in accordance with the De Beers Equipment Safeguarding Standard.

In addition, the section notes, "All designated crossings under the belt for persons shall be head protected."

In *California Code of Regulations, Title 8, section 3999 Conveyors*, CalOSHA notes:

> … unless a 6-foot 6-inch [≈2 m] headroom clearance is provided, employees shall not be permitted to pass under conveyors.
>
> Conveyors passing over areas that are occupied or used by employees shall be so guarded as to prevent the material transported from falling and causing injury to employees.

In many jurisdictions, crossunders—also known as underpasses—are regulated the same as crossovers. For instance, section 2.4.2.3 Crossovers for aisles and passageways of the Australian and New Zealand standard *AS/NZS 4024.3610:2015* provides requirements for both.

This standard specifies crossovers or underpasses shall be provided where access to both sides of the conveyor is necessary, such as the conveyor's head, tail, the drive, transfer(s), and other points as required. A crossover or underpass shall be provided where a conveyor crosses a walkway, aisle, or passageway and where the lowest part of the conveyor is less than 2.1 meters [≈7 ft] above the floor. The standard notes the underpass may be a crawlway where no alternative is practical.

In addition, where there is an underpass, the conveyor shall be guarded to prevent conveyor cargo falling onto workers passing underneath the conveyor.

The *AS/NZS 4024.3611*: Belt conveyors for bulk materials standard notes in section 2.10.2 that idlers accessible from underpasses and crossovers be protected by guards against accidental contact.

The need for guarding of the nip and shear points of idlers accessible from underpasses, crossovers, and crawlways is identified in *AS/NZS 4024.3610* Section 2.1.2(i).

Distance Between Crossing Points

Only a few authorities tackle the question of the distance between crossing point structures. The 7th Edition of *CEMA's Belt Conveyors for Bulk Materials* says, "Install a designated crossover or crossunder for every 1000 ft (305 m) of conveyor."

ASME B20.1-2015 6.1.1(e) specifies:

> On long overland belt conveyors where a pedestrian overpass or underpass is required, they shall be installed at intervals consistent with usage, normally not to exceed 300 m (1,000 ft).

The State of Washington's conveyor safety standards, published in *WAC296-806-42032*, specifies the "distance between overpasses should not exceed 300 meters or 1,000 feet."

Many long overland conveyors are patrolled by vehicle and in those cases the crossunders for vehicle traffic can be installed at much greater intervals than the distance specified by CEMA.

Local regulations may require shorter or allow longer distances. The need for convenient, yet safe, personnel movement inside facilities may require additional crossing apparatus. The number of crossovers and the intervals between may be controlled by requirements for emergency exits; this may be the first and most important criteria for conveyor crossovers.

REGULATIONS AND STANDARDS

The regulations covering conveyor crossing structures are typically very brief, and often refer to a region's regulations for ladders, scaffolding, and/or work platforms.

Australia

The 2015 Australian and New Zealand standard *AS/NZS 4024.3610* discusses crossovers in its section 2.4.2.3 Crossovers for aisles and passageways. The standard specifies that crossovers or underpasses shall be provided where access to both sides of the conveyor is necessary, such as the conveyor's head, tail, drive, transfer(s), and other points as required.

The standard further stipulates a crossover or underpass shall be provided at points where a conveyor crosses any walkway or aisle and where the lowest part of the conveyor is less than 2.1 meters [≈7 ft] above the floor. Where no alternative is practical, the standard allows the underpass to be a crawlway.

The standard notes in order to prevent a worker falling onto the conveyor, the crossover shall be equipped with handrails. Where there is an underpass, the conveyor shall be guarded to prevent conveyor cargo falling onto workers passing underneath.

In addition, the need for guarding of the nip and shear points of idlers accessible from underpasses, crossovers, and crawlways is identified in section 2.1.2(i) of *AS/NZS 4024.3611*.

Brazil

The only requirement for crossovers in Brazilian standard *NR-22 – Occupational Health and Safety in Mining* is found in section NR 22.8 Belt Conveyors:

> NR 22.8.4 – Personnel will only be allowed to cross over belt conveyors on walkways equipped with hand rail and kick-plate (toe-board). (**Figure 9.6.**)

Canada

Conveyor Belts section 4.4.16, of the *Health, Safety and Reclamation Code for Mines in British Columbia* notes the following:

> (2) No person shall cross a conveyor belt except at an established foot bridge not less than 500 mm [≈19.75 in.] in width equipped with guardrails.

Alberta's *Occupational Health and Safety Code 2009 Explanation Guide: Part 25 Tools, Equipment and Machinery*, notes in subsection 373(1):

> Workers crossing over a conveyor belt are at a risk of falling onto the conveyor belt or getting caught in moving parts. To prevent this, a bridge that is at least 1 metre [≈39.5 in.] wide and with adequate guardrails must be in place.

In the A*lberta Occupational Health and Safety Code*, published in 2009, section 373(2), the Alberta code provides that workers may "cross over a conveyor belt at a location other than a bridge if the belt is locked out." Finally, section 373(3) specifies:

> ... a worker must cross under a moving conveyor belt at a designated place where the worker is protected from moving parts of the conveyor and from material falling from the belt.

The Explanation Guide to the Alberta Code also notes in section 373(1):

> ... good practices include solid construction of crossover bridges, including steps and guardrails on both sides. The steps and floor of the walkway should be surfaced with non-slip material.

India

Indian standard *IS 7155.2 (1986) Code of recommended practice for conveyor safety, Part 2* notes in section 3.2.4.5:

> Where walkways are provided on both sides of a conveyor and where convenient access to either side of the conveyor may be required by employees, who regularly work in the area, crossovers shall be provided at appropriate intervals and at the head and tail ends of

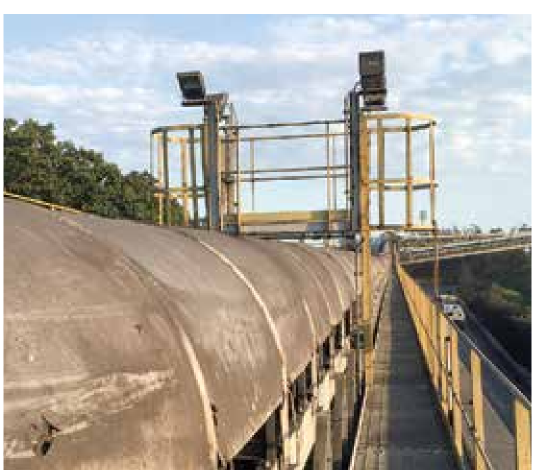


Figure 9.6.

This ladder crossover is furnished with a safety cage to prevent workers from falling.

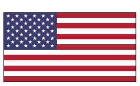
> the conveyors where no other crossing is available. Safe means of access shall be provided at crossovers.

Section 3.3.10 specifically forbids workers "to cross over or under an appliance [conveyor] except at the points specially provided for that purpose."

South Africa

In South Africa, the Conveyor Manufacturers Association of South Africa Limited (CMA) Guideline *Safety Around Belt Conveyors* section 6.3 Maintenance and Access echoes the concern that unless enough cross-overs are supplied, they will not be used by plant personnel. The guideline states:

> It is often necessary for an attendant to cross a conveyor at various points. … Where it is impossible to establish safe passageways underneath the belt, crossover bridges with handrails must be provided.
>
> The position of these bridges will depend on conditions at the belt conveyor installation, but unless a sufficient number are installed, they will not always be used.
>
> The crossover bridge must be accessed via stairs equipped with handrails and a 'toe-board' as well as an intermediate or knee rail. Avoid vertical ladders.



United States

CEMA SBP-001 notes conveyor cross-overs should meet the following applicable standards:

- *ANSI Standard A1264.1 – Safety Requirements for Workplace Floor and Wall Openings, Stairs and Railing Systems*
- OSHA's *29 CFR Part 1910.24 Fixed Industrial Stairs*
- OSHA's *29 CFR Part 1910.27 Fixed Ladders*

ANSI B20.1-1957 Safety Code for Conveyors Cableways and Related Equipment had the following regulations in its section 705 Crossovers, Aisles, Passages, and Stairways:

> All conveyors installed within seven (7) ft [≈2.1 m] of the floor or walkway surface shall be provided with crossovers or passages to comply with the requirements of the Building Exits Code A9.
>
> It will be permissible to allow passage under conveyors that are installed below the minimum seven (7) ft [≈2.1 m] headroom, excepting at main aisles and provided such passages are equipped with telltales indicating low headroom.
>
> All crossovers, aisles and passages shall be indicated by suitable signs in conspicuous positions.

However, a more recent version of this standard, *ASME B20.1-2015*, only contains one reference to crossovers. In section 5.10 Headroom, this new ASME standard states:

> It is permissible to allow passage under conveyors with less than 2 m [6 ft 8 in.] clearance from the floor for other than emergency exits if a suitable warning indicates low headroom.

The requirements from Occupational Safety and Health Administration (OSHA) and Mining Safety and Health Administration (MSHA) in the United States offer only limited guidance.

MSHA regulations are particularly vague. In *30 CFR 56.11013 Conveyor crossovers*, all that is said is the very fundamental statement "Crossovers shall be provided where it is necessary to cross conveyors." This is followed in *30 CFR 56.11014 Crossing moving conveyors*, by the similarly general comment, "Moving conveyors shall be crossed only at designated crossover points."

In *30 CFR 56/57.11002* (covering surface metal/nonmetal mines) and *30 CFR 77.205*, there is a further MSHA requirement that the crossovers (as well as other walkways) shall be in good condition:

> Crossovers, elevated walkways, elevated ramps, and stairways shall be of substantial construction provided with handrails, and maintained in good condition. Where necessary, toeboards shall be provided.

At the state level, the regulations can be somewhat more detailed. As an example, the state of Washington requires pedestrian overpasses for conveyors be provided. The regulation in *WAC 296-806-42022* requires a plant must:

- Provide a pedestrian overpass covering the full width of a passageway if one of these conditions exists:
  - The working strand of a conveyor crosses within three feet [≈915 mm] of floor level.
  - Workers must step over the strand and trough at or below floor level.
- Provide a pedestrian overpass where workers cannot pass under the conveyor safely.
- The sides of the crossing platform must have standard railings if one of the following exists:
  - The overpass is more than four feet [≈1.25 m] high.
  - The conveyor feeds a dangerous machine such as saws, chippers, hogs, or galvanizing tanks.

Under Title 8, section 7030 Conveyors, (d) of the *California Code of Regulations*, California OSHA (CalOSHA) notes the following:

> (11-2) (11-13) (11-14) Crossovers shall be provided and used where it is necessary to pass over exposed chain, belt, bucket, screw, or roller conveyors. Such crossovers shall be bridges or runways properly equipped with standard railings and toeboards, and shall have a fixed ladder, ramp, or stairway as a safe means of access.

This has been interpreted to mean that CalOSHA does not allow the use of the 'step across' conveyor height-style crossovers identified by CEMA as Types 1 and 2.

In the *West Virginia Code, section 22A-2-53c. Ramps; tipples; cleaning plants; other surface areas (7) Conveyors and Crossovers,* it is specified:

> Crossovers shall be provided where necessary to cross conveyors. All crossovers shall be of substantial construction, with rails, and maintained in good condition. Moving conveyors shall be crossed only at designated crossover points.

The West Virginia regulation concludes with, "Where it is required to cross under a belt, adequate means shall be taken to prohibit a person from making contact with a moving part."

The vagaries of these standards emphasize how critical it is to research and comply with local regulations.

BEST PRACTICES

The 7th Edition of CEMA's *Belt Conveyors for Bulk Materials* has identified the best practices for crossovers on belt conveyors as including: "Use CEMA type 3 or Type 4 crossovers in accordance with *CEMA SBP-001* or the most current version."

Other best practices include:

- Install a designated crossover or crossunder at distances not greater than every 1,000 feet [≈305 m] of conveyor length.
- Use crossunders when exposure to a nip point or pinch point is not considered guarded by location. The authors recommend that guarding by location is problematic. All nip points should be guarded and all return idlers guarded to prevent falling idlers. (**See Chapter 11 The Myth of 'Guarded by Location.'**)
- Place crossing structures where a worker is not able to exit or enter a travelway directly. A barrier should be constructed that requires the worker to turn in order to

enter or exit the crossover/crossunder. This improves safety by preventing the accidental or unknowing entry of or falling from the crossing structure onto the moving belt or nearby traffic patterns. In keeping with this, new construction should take into consideration plant traffic patterns to determine locations for travelways and crossing structures.

- Do not place crossing structures where spillage or accumulation of fugitive materials is expected or commonly occurs. Spillage accumulated on the crossover/crossunder steps or landings can cause slips, trips, and falls. The slip, trip, and fall hazard can be mitigated by proper location of the crossover/crossunder.
- Protect the areas where crossovers/crossunders are used as travelways during inclement weather. The crossover/crossunder should be protected from falling material, ice, snow, and accumulations of water.
- Construct steps, rungs, and landings with non-slip/non-accumulating materials such as grating, perforated planks, or fiberglass grating impregnated with grit.
- Construct crossovers/crossunders according to local regulations for stairs and work platforms, which may include handrail dimensions, mid-rail and toeboard requirements, and exceed minimum load requirements.
- Provide adequate lighting.
- Where headroom clearance is less than 2 meters [≈6 ft 8 in.] provide low headroom warnings.
- Crossovers and crossunders should be painted to be clearly identifiable as safe passage ways.

CLOSING THOUGHTS

As noted in CEMA's *Safety Best Practices Recommendation*:

> Proper application of crossovers at the 'most needed' locations can go a long way towards promoting workplace safety when conditions would otherwise present the temptation to cross the conveyors in an unsafe manner.

Make sure the crossing point structures are in compliance or exceed local regulations for construction, path width, elevation above the belt, and other characteristics. (**Figure 9.7.**)

The CEMA *Conveyor Crossovers Best Practices* publication *SBP001-2014* notes:

> Specific conditions will vary from application to application, as will the purposes and experience level of the personnel expected to use the crossovers. These varying conditions, purposes, and experience levels will affect the selection of the type and design of the equipment provided in any given situation. … The interests of practicality, utility, and safety are of prime concern in evaluating any proposed design.

The provision of more than the minimum required number of crossing structures will help to eliminate the carelessness and unconscious risk-taking that can lead to severe injury.

It remains important that owners specify and designers include proper crossing structures. It is also important that plant management reinforces that the plant's crossovers and crossunders are used for all passages across or under each conveyor. ⚠

Figure 9.7.

Conveyor crossovers should comply with regulations for the construction of stairs and walkways.

2

Chapter 10 Guarding

INTRODUCTION

On conveyors, as well as on other machinery, guards form a barrier to provide a positive protection, keeping workers distant from the hazards of moving parts.

In this chapter, we will consider what some have called 'hard guarding,' those (usually flat) panel guards that are installed closely to a conveyor's nip points to prevent worker contact with these hazards. (**Figure 10.1.**) The discussion in this chapter covers barrier guards for belt conveyors; other forms of safeguards—like roller baskets, return-roller nip-point guards, conveyor crossovers, and fugitive material nets—will be considered in other sections of this book.

The Goal of Guards

The Performance Criteria for Safeguarding, published by the American National Standards Institute (ANSI) as standard *B11.19* defines safeguarding as "the protection of personnel from hazards by the use of guards, safeguarding devices, awareness devices, safeguarding methods, or safe work procedures."

In 1946, the National Safety Council (NSC) in the United States published the first edition of its *Accident Prevention Manual for Industrial Operations*. This volume compiled a summary of previous and then-current concepts and technology regarding industrial safety and accident prevention.

According to the Nelson & Associates fact sheet, *Machine Guarding 1946-1970*, after noting that 25 percent of all permanent disabilities result from machinery accidents, the *NSC Accident Prevention Manual for Industrial Operations* adds:

> ... Positive guarding of point of operation hazards should be relied upon rather than a machine operator's consistent obedience to safety rules. Every effort should be made to make a guard so positive in action that human failure cannot cause an accident.

Thus, all moving machine parts should be guarded with adequately constructed, properly installed, functioning, and well-maintained guards to provide the necessary degree of protection.

Properly designed, installed, and maintained fixed guards offer the added advantages of low cost, compact design, and high reliability. However, guards are not a substitute for locking out the system, especially when clearing obstructions and performing maintenance.

What We Mean by a Guard

A guard is a physical barrier that prevents or reduces access to a hazard or danger point. Guards are designed to isolate the hazard from the worker (or the worker from the hazard) by distance or inaccessibility. As defined in the United Kingdom's *Guide to application of the Machinery Directive 2006/42/EC Annex I*, item 1.1.1 (f), a guard is "a part of the machinery used specifically to provide protection by means of a physical barrier."

Fixed Guards

Fixed guards are intended as a permanent part of the machine. They are not dependent upon moving parts to function. They are often preferable to other types of safeguarding because of their relative simplicity.

Fixed guards are also known as barrier guards because they form a barrier to keep workers away from a hazard created by equipment. A fixed guard by its design and construction (and by its presence) prevents access to the dangerous part for which it is provided. Such a guard has no moving parts associated with or dependent upon the machine to which it is fitted. It is reliable and requires little maintenance.

Properly installed fixed guards protect workers from the hazardous parts of machines at all times. They offer advantages in that they can be constructed—often in the plant where the equipment is used—to suit specific applications in order to provide maximum protection with minimum maintenance.

The limitations of fixed guards include the potential to interfere with visibility. In addition, machine adjustment and repair may require removal of the guards, thereby requiring other additional means of protection for maintenance personnel.

Interlocking Guards

Interlocking guards are designed so that the machine on which one is installed will not operate unless the interlocking guard is in a closed position. Often these guards are moveable by means of hinges or tracks. Opening

Figure 10.1.

Barrier guards should be installed to keep workers away from a belt conveyor's many nip points.

2

the guard while the machine is in motion will cause the machine to shut down.

When an interlocking guard is removed or opened, the tripping mechanism and/or power automatically shuts off and disengages, the moving parts of the machine are stopped, and the machine cannot be started until the guard is back in place. As an example, access doors that admit maintenance personnel can be interlocked with the equipment's power supply to shut down automatically if unauthorized entry is attempted. Even when the stop function is initiated, it may take some time for the conveyor to come to a stop.

Interlocking guards should be so constructed and located that they cannot be readily tampered with or defeated. If a component of the interlocking mechanism fails, the machine should not be capable of being set in motion. Interlocking guards require a reliable system of regular testing and inspection, and in turn they may need a high degree of maintenance.

Guarded by Location

Guarding that is the result of the physical inaccessibility of a particular hazard under normal operating conditions is called 'Guarding by Location.' Machinery may be safeguarded by location if the distance to dangerous moving parts is greater than the prescribed safety distance, which varies by jurisdiction. This is most often seen in hazardous components that are located out of reach overhead.

If, due to work requirements, access to hazardous locations is gained by use of ladders, scaffolds, and so on, temporary guarding or lockout procedures must be used.

When the elevation is subject to changes—due to the accumulation of stored or fugitive material, for example—an installation previously seen as safe because it was 'guarded by location' may now pose a hazard. (**Figure 10.2.**) (**See Chapter 11 The Myth of 'Guarded by Location.'**)

Figure 10.2.

The accumulation of fugitive material can expose workers to hazards in an area previously identified as 'guarded by location.'

Area Guarding

Equipment occupying a large area and having numerous moving machine parts may be a good application for area guarding. An area guard is a barrier which prevents entry of a worker into an area that contains moving machine parts, thus preventing contact with the moving parts.

Area guarding makes sense if a specific location contains several hazards, and hence it becomes more sophisticated and more economical to provide a safeguard that prevents contact with all the hazards, rather than to put each individual hazard behind individual point-of-contact guards. Effective area guards require additional practices and provisions such as signage, locks, or color coding in addition to the physical barrier.

As an example, an area guard might be used to protect miners from multiple hazards at a conveyor head pulley. (**Figure 10.3.**) In this instance, the multiple hazards include the head pulley and shaft, the keyway and key, the in-running nip point between the pulley and the belt, and the system's V-belt-and-motor drive.

Guarding a conveyor's drive system and head pulley is often an acceptable application for area guards for several reasons. Access is infrequent and several hazards are made active by one motor. The mine operator can implement additional practices and controls, including signage and lockout / tagout procedures.

A disadvantage of area guarding is that the use of proper individual point-of-contact guards could allow one belt (or system) to be serviced while another system (or belt) could continue to operate. An area guard here would require shutting down the entire area, that is, both belts.

Another disadvantage of area guards is that all systems with hazardous moving parts will need to be individually locked out and tagged out before entering the guarded area.

Area guards often require additional administrative controls and practices. Locations with area guards will typically require the establishment of proper procedures and training of personnel in those procedures. Affixing a sign that warns that this is an area guard and that special entry procedures and work practices are required would further reduce risk of injury.

There is some controversy about the indiscriminate use of area guarding in place of point-of-contact guards. Critics argue that point guards are often still required within guarded areas.

Area guards may be most effective where the hazards are latent rather than active. For example, a handrail or chain link fence preventing casual travel under a conveyor may be more effective and easier to maintain than individual return-idler catch baskets or nets to catch falling bulk materials. Area guards lend themselves to controlled access locks and proximity sensor interlocks.

The Criteria for Guards

In 1946, the National Safety Council (NSC) in the United States published the first edition of its *Accident Prevention Manual for Industrial Operations*. As noted in Nelson & Associates fact sheet, *Machine Guarding 1946-1970*, the NSC manual presented the goals for guards as:

1. Provide positive protection.
2. Prevent all access to the danger zone during operation.
3. Cause the operator no discomfort or inconvenience.
4. Not interfere with operation.
5. Operate automatically or with minimum effort.
6. Be designed for the job and the machine.
7. Preferably be a built-in feature.
8. Provide for machine oiling, inspection, adjustment, and repair.
9. Withstand long use with minimum maintenance.
10. Resist normal wear and shock.
11. Be durable, fire- and corrosion-resistant, and easily repaired.
12. Not constitute a hazard itself (without splinters, sharp [or] rough edges, or other sources of injury).
13. Protect against any contingency, not merely against normal operations.
14. Conform with the provisions of American Standards Association codes (now ANSI).

Since that time, some lists of the criteria for effective guarding have been very brief, as seen in the list in section 8.1.2 of *Best Practice: Conveyor Belt Systems*, issued in 2001 by South Africa's Safety in Mines Research Advisory Committee (SIMRAC). In turn, the *SIMRAC report* cited Canada's Mine and Aggregates Safety and Health Association (MASHA), saying:

> To effectively guard moving machinery, MASHA recommends guarding that:
>
> - Prevents access to danger zones
> - Is light enough to be handled

Figure 10.3

An area guard can be installed to keep workers away from multiple hazards.

Image courtesy of the United States Mine Rescue Association.

2

- Is painted with bright colours to quickly indicate missing guards.

At the other extreme is the list of 17 considerations offered in the Mine Safety and Health Administration (MSHA) publication, *MSHA's Guide to Equipment Guarding*. While applicable for guards on all machinery, this guide devoted most of its commentary (and its illustrations) to belt conveyor guarding. As the publication notes, the goal of the list is to present "a discussion of effective guard design and use, and is not a requirement for compliance." (**See MSHA Guarding Considerations and Recommendations.**)

What Must Be Guarded

In the United States, the Occupational Health and Safety Administration (OSHA) Machinery and Machine Guarding standard, *29 CFR 1910.212(a)(1)*, requires employers to ensure machine hazards are safeguarded.

MSHA Guarding Considerations and Recommendations

In the United States, MSHA has listed the considerations for guards in its 2004 booklet, *MSHA's Guide to Equipment Guarding*. The publication is available as a PDF for free download from *msha.gov*.

MSHA Guarding Considerations and Recommendations

This section is written as a brief discussion of effective guard design and use and is not a requirement for compliance.

- Do the design, construction, selection of materials and guard installation prevent contact with all moving machine part hazards?
- Does the guard provide protection by itself, and not rely on visual or tactile awareness of a hazard, administrative controls or procedures such as warnings, signs, lights, training, supervision or personal protective equipment?
- Are the guard material(s), fastening methods, and construction suitable to withstand the wear, corrosion, vibration and shock of normal operations?
- If drive belts inside a guard fail, will the whipping action of broken belts be contained?
- Is the guard recognizable as a guard?
- Is the guard installed securely?
- Is the guard design adequate for the application and specific hazard(s)?
- Are openings in the guard material such that contact with the hazard is prevented by the distance between the guard and the hazard?
- Does the guard interfere with the normal operation, inspection, lubrication or servicing of the equipment?
- Is the guard designed and constructed so that adjustments to the guarded components can be made without loss of protection or modifying the guard?
- Do the design, materials and guard construction prevent the guard from being a hazard itself (i.e. free of burrs, sharp edges, pinch points, etc.)?
- Is the guard of a size, shape, weight and balance which permits safe manual handling when it is removed or replaced? Alternately, if it is too large for manual handling, is it accessible and amenable for safe handling with mechanical tools or equipment?
- Is the guard constructed so that it cannot be circumvented, by-passed or overcome?
- Can the guarded components be inspected without removing the guard?
- Is the guard constructed and located so as not to hinder clean-up efforts?
- Is the guard maintained in serviceable condition?
- Have you considered the use of new technology, if applicable?

The text reads:

> One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks.

Similarly, MSHA's requirements, published in *30 CFR 56/57.14107(a)*, states:

> Moving machine parts shall be guarded to protect persons from contacting gears, sprockets, chains, drive, head, tail, and takeup pulleys, flywheels, couplings, shafts, fan blades, and similar moving parts that can cause injury.

In its section 2.10.2, the Australian/New Zealand standard *AS/NZS 4024.3611 Safety of Machinery – Conveyors – Belt Conveyors for bulk materials handling* provides a detailed list of the nip and shear points that need to be guarded. These hazard points include drive, head, bend, and snub pulleys, as well as carrying and return idlers in transition zones, at convex curves, and beneath feed hoppers and skirtboard steel. The regulation also mentions idlers which are accessible from crossovers, underpasses, and crawlways, and idlers in positions where the belt can be lifted less than 60 millimeters [≈2.36 in.].

In section 2.10.3, the Australian standard reiterates that both carry and return idlers need to be guarded when there is a shear point caused by the idler and other components, or there is enough force down on the idler to present a hazard.

The standard also points out the need to guard other components where a risk is present, and specifically lists belt cleaners and belt tracking idlers.

Because of the differences in the design, construction, and application of conveyors, it is difficult for any regulation to be more specific than as provided in the Australian standard.

The Special Challenges for Guards on Conveyors

Guards on belt conveyors are used for a number of unique circumstances and challenges. (**Figure 10.4.**)

Most machine guarding is concerned with preventing contact with powered machinery. Thus, a conveyor power system and drive pulley requires guards. But in numbers alone, these power components are vastly outnumbered by a belt conveyor's freely rolling components, for example, idlers and unpowered pulleys. Free-rolling components, powered by the belt, can create pinch points. At a minimum these rolling components should be subject to a risk assessment to review their need to be guarded.

Users should be aware that reversible belt conveyors have nip points that must be guarded for both directions of travel.

Effective fixed guards should be absolute in their protection; workers should not be able to reach around, under, through, or over the guard. The guards also need to be easy to install and reinstall, allowing inspection and simple equipment service. They should be fairly easy to remove—when the conditions are proper, for example, when the conveyor is locked out—and to reinstall. This will make sure the guarding is returned to its proper position when the service procedure is over and before the conveyor is returned to operation.

Figure 10.4.

Guards on belt conveyors are needed to control the hazards on a number of unique conveyor-related circumstances.

Image courtesy of the United States Mine Rescue Association.

Allowing Inspection

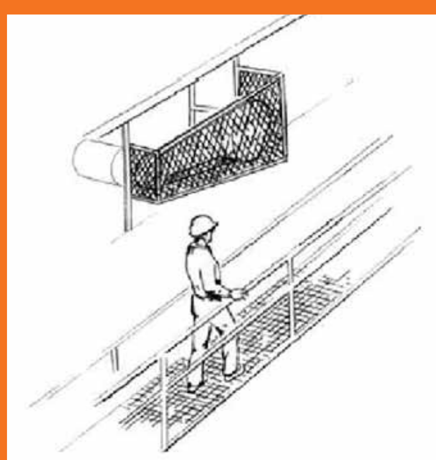
Inspection remains a key requirement of successful plant operation. In fact, the need for inspection is the main reason many (if not most) guards are constructed with screen, mesh, or expanded metal sections in the guard. The use of these materials allows plant personnel to safely check on components inside the guard.

Guarding Drives and Belts

Like other powered machines, conveyors need to be guarded on their drive systems. Some belt conveyors use a V-belt; others use a shaft to turn the drive pulley(s), which in turn pulls the cargo-carrying belt through the system. Both power systems contain rotating components that present moving-part hazards to unwary workers and so should be guarded.

In addition, in the United States, MSHA regulations in *30 CFR 56/57.14108* require "overhead drive belts shall be guarded to contain the whipping action of a broken belt if that action could be hazardous to persons."

Other jurisdictions spell out in more or less detail their variation on the requirements for the guarding of belt conveyor drive systems.



MSHA regulations require overhead drive belts be guarded if a broken belt could create a whipping action that could be hazardous to workers.

There are a number of reasons why most guards are composed of a mesh material. Among the reasons are:

A. Workers can see through them to assess problems without removing the guard.

B. They are lightweight, yet strong.

C. They prevent material buildup within the guard by allowing it to fall through. At the same time, they will prevent most material from being cast out of the enclosure.

D. The guard can be cleaned inside and out without needing to be removed (for example, by a water spray).

E. No special (or additional) openings need to be made to install extended grease fittings.

When possible, worker visibility of the production process should be unobstructed by machine guards or devices. Unhampered visibility can help operators identify malfunctions, misalignments, and other potential hazards.

It is important to select proper guard materials and to assure that they provide sufficient visibility.

Guards and Maintenance Procedures

It is important that guarding not interfere with the normal operation of the conveyor. In addition, the guarding should not unduly interfere with the inspection, lubrication, and service of the system. If the guard impairs an individual operation or the entire process, it is likely—or perhaps inevitable—that the guard will be removed.

Care has to be taken when installing guarding to ensure that no new hazards are introduced and, at the same time, that plant efficiency does not suffer. For that reason, it is essential to consult with managers and equipment (or process) operators before designing and installing the new guarding.

Additional measures can also be taken, such as fitting remote grease points, so the conveyor can be lubricated without having to remove guards, and manual takeups can be operated from outside the guards.

Guarding should also be designed, so far as possible, such that routine cleaning and clearing of spillage can take place without entering the danger zone and without disturbing the guarding.

Reinstallation is Critical

José Sanchez, writing in an article, "Conveyors – Guarding Against Inadequacy," in the Government of Western Australia Department of Mines and Petroleum's Resources Safety Division publication, *MineSafe*, noted:

> Incidents where personnel have been injured by moving parts of conveyors have usually been caused by the absence of guarding rather than the method of guarding. (**Figure 10.5.**)

The best guard cannot keep any worker safe if it is lying on the floor away from the hazard. It cannot protect workers if it is not properly installed and maintained.

A Performance Standard

In most cases, the standards for guards on conveyors emphasize that the guidelines are aimed at achieving the goal of worker safety, rather than specifying any construction or installation detail.

By not specifying the types of guard that must be used, these standards present a 'performance' standard. That means the employer is free to use any guard that performs in such a manner as to meet the objective. In this case, the objective is to protect employees from the identified hazards. If the regulatory agency had specified the type(s) of guards that must be used, the standard would be a 'specification' standard.

As a result, the first criteria for suitability of a guard is: Will it prevent contact with the moving machine hazards? That means a guard must be designed, constructed, and installed so that it cannot be circumvented, bypassed, or overcome. If the guard does not protect workers from coming too close to a hazard, there is no need to consider whether it is the right color or if it is properly fastened to the equipment. The question is summarized in the words from *MSHA's Guide to Equipment Guarding*: "Do the design, construction, selection of materials and guard installation prevent contact with all moving machine part hazards?"

Performance standards are open to interpretation by inspectors. Therefore, suppliers cannot certify compliance with guarding performance standards, much to the dismay of the purchaser of the machine. Specification standards are routinely used in the design of conveyors, and a move toward more prescriptive standards for the design, fabrication, and installation of conveyors might be a welcome change for operators subject to the opinions of individual inspectors.

A Guard Must Stand Alone

A guard should be fully functional by itself. It cannot require the presence of additional equipment or personnel to provide effective protection. It should keep workers safe without needing additional signs or signaling mechanisms and without requiring additional training in hazard recognition or safe working procedures. It must provide protection without needing a power supply or external control systems. With those interlocking systems that require electrical connection, the guard should provide a basic level of protection even if the external power is lost.

Figure 10.5.

No matter how well it is designed and built, no guard can improve conveyor safety unless it is installed (and replaced after service) on the conveyor.

Image courtesy of the United States Mine Rescue Association.

2

Recognizable as a Guard

In order for workers to perceive the danger of a particular hazard, a guard must be recognizable as a guard. This helps workers understand the danger areas of a machine and emphasizes the importance of replacing a guard that has been removed.

The simplest way to make a guard recognizable is to adopt a stand-out color scheme that is consistent throughout the facility. When a guard is painted the same color as the rest of the machine, it is difficult to note the presence and importance of a guard. (**Figure 10.6.**) It has become merely an access cover or other component of the machine.

The idea behind color-coding is to make the employee aware of potentially hazardous conditions. Therefore, guards should be painted a color used only for guards. The most typical colors for guarding systems are 'safety yellow' or 'safety orange.' Both are readily available in standard industrial or consumer paints. If all plant equipment were yellow, the guard could be orange, or another distinct color. Regardless of the color chosen, it is important the color makes the guard stand out. (**Figure 10.7.**)

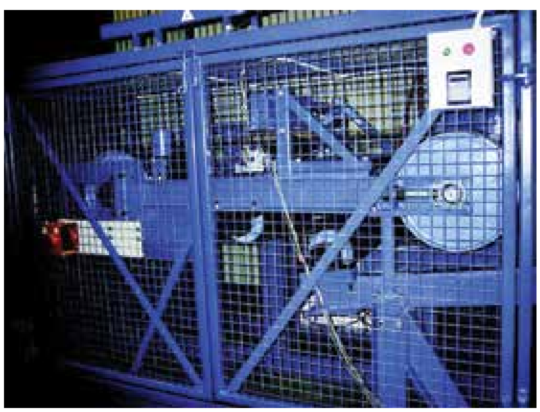


Figure 10.6.

Guards should not be painted the same color as the equipment being guarded.

Image courtesy of the United States Mine Rescue Association.

Figure 10.7.

Regardless of the color chosen, the color of a guard should differentiate it from equipment and indicate it is a guard.

Various standards often require specific colors be used on hazards themselves, rather than on the guards of the hazards.

In the United States, OSHA requirements under *29 CFR 1910.144* provide specific color-coding requirements for items such as safety cans or other portable containers of flammable liquids, and for devices such as emergency-stop buttons, switches, and bars; beyond that, the standard does not specify what machines or portions of machines need to be color-coded.

OSHA specifies in *29 CFR 1910.144(a)(3)* that yellow is a preferred color for indicating physical hazards. This regulation notes, "Yellow shall be the basic color for designating caution and for marking physical hazards such as: Striking against, stumbling, falling, tripping, and 'caught in between.'" Red was reserved to indicate danger, as well as for use on fire protection equipment and emergency-stop controls. The color(s) for guards is not specified, and the color orange not mentioned. While *29 CFR 1910.144(a)(3)* does recommend yellow, it does not specify where and how much of a machine or a physical hazard needs to be marked.

It must be noted that this regulation is pointed at the hazard itself rather than the guard. If the guard of a machine does not present a physical hazard such as, but not limited to, tripping, falling, struck by, or caught between, there would be no need for it to be color-coded.

It must be emphasized that color-coding of the hazard in no way eliminates the need for adequate guarding of the piece of equipment. Physical hazards created by operating machinery must be addressed by compliance with Subpart O of *29 CFR 1910, Machinery and Machine Guarding*.

As a final note on guard color, the article, *The Do's and Don'ts of Fixed and Moveable Machine Guards, Part 1*, by John Peabody advises that the *ANSI B11.19-2010 Performance Cri-*

teria for Safeguarding specifies, "If mesh or expanded metal [is used in a guard], the color of the barrier material should be darker than the area observed to enhance visibility." (**Figure 10.08.**)

The Canadian publication, *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*, jointly produced by Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) and Commission de la santé et de la sécurité du travail (CSST), notes:

> In order to reduce as much as possible the number of times guards need to be opened, guard construction should be such that the protected components can be easily seen. Therefore, it is suggested that the screen of the guard be painted in a dark colour (flat black, charcoal grey), with the frame in a light colour. By painting hazardous machine components in bright, contrasting colours, attention is drawn to the danger zone when a guard is opened or removed.

In summary, the key is that the guard must draw attention to the hazard and to its own status as a guard; color is one means of doing that.

At a recent Training Resources Applied to Mining (TRAM) conference presented by MSHA in the United States, a plant operator remarked that over the years, different inspectors had required the plant paint its guards different colors a total of 13 times! This type of overreach by regulators and questionable direction by inspectors are part of the reason that the industry should standardize permissible guard color(s) and prohibit the use of those colors on the main machine. This would do much the same for the accepted guard color as has been done with the color red, which is now generally reserved for fire protection and safety warnings.

Not a Hazard in Itself

The guard must be designed and constructed well enough that its presence and handling do not create a risk for injury. That means no sharp edges nor pointed projections. The guard should feature framed or banded edges, so that there are no surfaces that can injure workers. (**Figure 10.9.**)

And of course, guards must never be positioned or fastened to moving parts in a way that creates any kind of pinch point.

Another consideration is the ability to handle a guard. The guard must be able to be removed, maneuvered, and stored, and then maneuvered and reinstalled, without risk to the worker(s) charged with that task.

It is important to give consideration to ergonomics when designing guards. This concern is to improve handling and to avoid injuries. In its 2010 training presentation, *Guarding Conveyor Belts at Metal & Nonmetal Mines*, MSHA noted that approximately 45 percent of guard-related injuries occur when a miner mishandles a guard and drops it on oneself or

Figure 10.8.

Some standards recommend the mesh in a guard be painted a darker color to improve visibility of the hazard inside the guard.

Image courtesy of the United States Mine Rescue Association.

Figure 10.9.

A guard with sharp edges and projections creates a hazard in itself.

Image courtesy of the United States Mine Rescue Association.

2

on someone else. Many of these injuries could be prevented if guards were easier to pick up, hold, and carry.

Guards should be of a size and shape that allow for easy handling, preferably by a single worker. (**Figure 10.10.**) The size, weight, and shape of the load should not interfere with vision. A risk assessment needs to take into account the increased risk of slipping, tripping, or falling when manually handling a cumbersome guard.

To make guards easier to handle, guards should be of a reasonable size and weight or incorporate a means to improve handling by sliding, rolling, or mechanical lifting. Ergonomics should also be considered to avoid the need for awkward body positions or postures when removing or replacing guards.

Weighty Thoughts

While there are no prescriptions for the maximum weight of a guard, good ergonomic practices should prevail in the design of each guard. The now-superseded Australian standard *AS 1755 Conveyors – Safety requirements* offered a reminder in clause 3.1 that suggested special note be taken of the weight of guards that would need to be raised into position by personnel.

Figure 10.10.

Guards should be designed for lifting and removal by a single worker.

A number of sources offer calculators for determining the appropriate weight limit for manual lifts. The choices include spreadsheets, formulas, and automated calculators. The National Institute for Occupational Safety and Health (NIOSH) offers a lifting equation to calculate a Recommended Weight Limit (RWL).

The Michigan Occupational Safety and Health Administration provides a succinct explanation:

> In essence, the NIOSH lifting equation begins at 51 pounds (23 kg) and conditions involved with the lift will lower the RWL. The factors … include the horizontal location of the load, the vertical location of the load, the vertical travel distance involved with the lift, and the frequency of the lift. Although the NIOSH lifting equation begins at 51 pounds, again that is not considered to be the maximum weight an employee can lift. Under optimal condition such as low frequency of lifts, good coupling, and good posture a greater amount of weight can be safely lifted.

Some guarding standards require—and so some guard manufacturers provide—the weight of each guard to be inscribed into each panel. This allows plant personnel to assess the risks of manual handling of the guard prior to its removal and so determine if supplemental material handling aids are appropriate.

More important than just the sheer weight is the position of the guard in relation to the position of the worker(s) who will be removing or replacing it. Some jurisdictions offer guidance as to the maximum weight or force to open that should be allowed, based on the position of the object and the movements expected from a typical worker.

Markings on Guards

Some standards, in addition to marking the weight to assure safe handling impose additional marking requirements for guards. Some

2

standards require that guards be marked in compliance with the European Conformity (CE) standards.

In addition, it may be beneficial for guards to show some form of location code, to aid in the prompt and proper reinstallation of the guard.

Of course, it is good practice to include signage on any guard warning people not to remove the guard without first isolating the conveyor. Warning signs may be needed on each removable panel announcing the need for Lockout / Tagout procedures prior to removal of the guard.

Handles and Other Aids for Lifting

In section 2.13.4.8, the Australian and New Zealand standard *AS/NZS 4024.3610 Conveyors – General requirements* requires handles on guards. It notes that lifting handles offer a safe method for the opening of doors and the removal of guards. (**Figure 10.11.**)

Handles to improve a guard's maneuverability can be provided on guard panels by suppliers or added by installers. Handles are available as external devices applied to the guard, or as grips folded out from the surface or frame of the guard panel (**Figure 10.12.**), or as areas where material in the frame has been removed to form a handhold.

On handholds created with an opening or a fold-out section, it is important the open space created for the grip does not create an exposure to the hazard. When handles are applied, care must be taken not to add a hazard in the form of a cumbersome or potentially hazardous extension of the guard.

If a guard is too heavy or too bulky for safe handling by one person, provision should be made to allow mechanical assistance. This could come in the form of fittings on the guard which facilitate the use of a lift, dolly, or other aid when removing or reinstalling the guard. Oversize guards should be marked as requiring mechanical assistance or needing more than one worker for removal.

Strength of a Guard

Most strength requirements merely refer to the Performance Standard, meaning that the judgement of whether a guard is strong enough is determined by its ability to maintain the appropriate safety distance and keep workers away from hazards, and its ability to withstand being fallen or climbed upon.

In its discussion of guard strength in clause 2.13.4.4, the Australian and New Zealand standard *AS/NZS 4024.3610 Conveyors – General requirements* specifies guards be designed to withstand the anticipated loads without suffering a reduction in the prescribed (distance-to-hazard) safety distances, which are detailed in the following clause, 2.13.4.5.

Figure 10.11.

Handles can be added to guards to provide a safe method for removal.

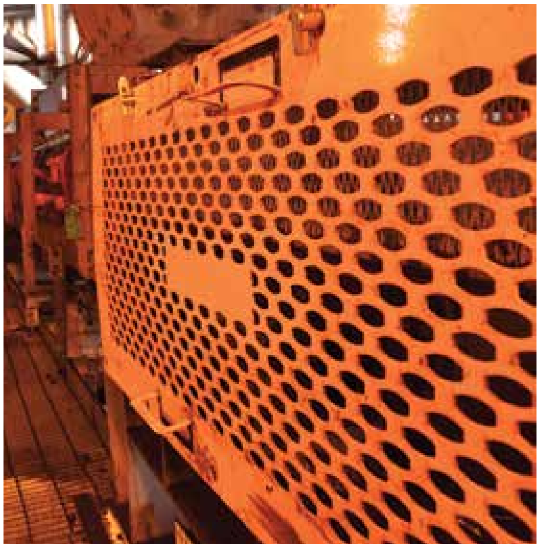


Figure 10.12.

Fold-out handles incorporated in a guard's design improve the handling of the panel.

Clause 2.13.4.4 goes on to specify, in order to withstand the stress of a worker leaning against it, a guard should withstand a force of 450 neutons [≈101 lb_f] applied at a right angle to the surface over a square area of 50 x by 50 millimeters [≈2 by 2 in.] at any point on the guard.

To withstand the stress of being climbed or rested upon, guards should withstand a force of 900 newtons [≈203 lb_f] applied vertically in combination with a simultaneous horizontal force of 220 newtons [≈50 lb_f]. (**Figure 10.13.**)

In addition, the clause notes guards should withstand the load from any accumulation of spilled cargo.

ISO 14210 specifies test methods for guards and includes a requirement for retaining flying objects.

Materials of Construction

In the United States, MSHA requirements in *30 CFR 56/57.14107* and *.14112* clarify that the standard is performance-oriented and do not specify what materials may or may not be used. As summarized in *MSHA's Guide to Equipment Guarding*, "MSHA requirements are based on the level of protection provided, not the choice of materials for guard construction." Instead, specification and selection of the materials of which a guard is to be made should be based on a review of conditions of the application.

For Australia, the standard *AS/NZS 4024.3610* lists a restriction on metal construction materials used in an underground coal mine. In clause 3.2.3, the standard specifies that no light metal should be used in the construction of any conveyor equipment's external surfaces. The regulation then defines light metal as "aluminium" [in North America it is spelled 'aluminum' – Ed.], magnesium, titanium, or alloys containing more than specified percentages of those metals.

To MSHA in the United States, any materials are acceptable if they meet the performance objective of the guarding standard; that is, they withstand the vibration, shock, and wear to which they will be subjected during normal operations, while effectively preventing worker contact with hazardous moving machine parts.

An article available from *ehstoday.com*, "The Do's and Don'ts of Fixed and Moveable Machine Guards, Part 1," by John Peabody, offered these guidelines:

> Materials used in fabrication of fixed guards [must be] of adequate strength or durability. ... Materials that can break, bend, or distort are not acceptable. Similarly, materials that deteriorate in the presence of airborne swarf [chips or particles], ultraviolet radiation, temperature extremes, oils, coolants, solvents, cleaners or other environmental contaminants/agents can compromise the intended protection of fixed guards.

The speaker notes included with a 2010 MSHA PowerPoint presentation, *Guarding Conveyor Belts at Metal & Nonmetal Mines*, provides the following:

> Examples of metals that may be used are sheet metal, expanded metal mesh and metal floor grating.

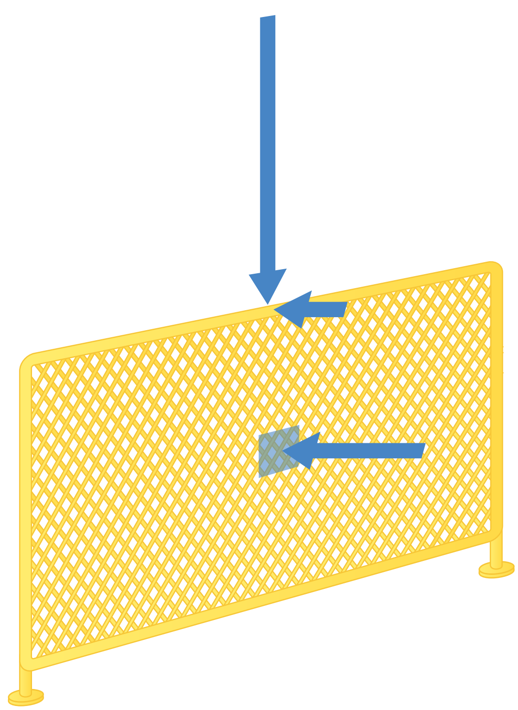


Figure 10.13.

To bear the stress of being walked or rested upon, guards should be able to withstand simultaneous horizontal and vertical forces.

> Other examples of metals that may be used are chain link fencing, metal mesh and punched plate, such as that used in screen decks.
>
> Chain link fencing is more flexible than some materials and may require the frame's members to be more closely spaced or firmly supported to prevent the fencing from deflecting into a hazard, such as if someone were to fall against the guard.
>
> Used metal screen cloth … may be recycled [into a guard] if it remains in good condition and does not present a hazard, such as having broken or protruding wires that may lacerate or puncture.
>
> Rubber is tough and flexible and has guarding applications. Rubber guards, like all guards, must be substantially constructed and fastened securely in place. Rubber guards may not be acceptable in high wear areas, in high heat areas, near certain chemicals or where they may be easily ignited.
>
> Durable plastic guard systems are available. Plastic may not be acceptable for high heat areas or near certain chemicals. … Plastic construction-type fencing weathers poorly, deflects and cuts easily. It is not substantial or durable and is not acceptable for guarding, even if stretched over a rigid frame.
>
> Wood is acceptable if it is substantial, secure and maintained. It might not be appropriate in wet conditions or where high heat, or other ignition sources are present.
>
> Materials from which guards are constructed do not have to be new; but if they have been used before, they must not present a hazard in themselves.

Guard Installation

A key requirement for a guard is that it can be installed, removed, and reinstalled after service efficiently and without impairing its function. Guards and the mechanism by which they are mounted must allow efficient removal and reinstallation. This will reduce the possibility that, once removed, the guard will be inadvertently, or purposefully, left off.

One way to accomplish this is by attaching the guard in place so that it cannot be easily moved out of the way or inadvertently bypassed by moving or bumping it out of its intended position. A guard must be installed securely enough so that the force of someone falling against it does not dislodge it to allow the falling person to enter the danger zone. (**Figure 10.14.**)

In its 2010 compliance resource, *Guarding Conveyor Belts at Metal & Nonmetal Mines* PowerPoint presentation, MSHA explains that:

> Standard *56/57.14112* requires guards to be securely in place when the equipment is operating. For a guard to be considered securely in place, it must not be easily moved aside. Guards may be considered securely in place if they are fastened, or if their size, mass, or weight causes them to hang or rest so they cannot be easily moved away/aside.
>
> Fastening a guard in place is one way to prevent it from falling off or slipping away from the position in which it is intended to be, and preventing it from being easily bypassed by sliding, moving, or brushing it aside or out of the way. Fastening will also prevent a guard from being inadvertently removed.

Figure 10.14.

A guard should be installed so that a worker falling against it will not dislodge it from position.

2

> Some guards are heavy or bulky enough that they cannot be easily moved from the position in which they were set. For instance, guards may be hinged at the top and hang in place.
>
> The standard does not require guards to be immovable, secured on all sides, or to be removable only with the aid of tools. It does require a guard to be an effective barrier to protect miners from inadvertent and purposeful work-related contact with moving machine parts.

And yet guards should be able to be removed without damage, so that when returned to position, they remain as effective deterrents to worker contact with the hazards.

2

Fastened in Place

Guards can be attached to the conveyor structure with a variety of fasteners. (**Figure 10.15.**)

OSHA, MSHA, and the Occupational Health and Safety Act specify different methods to fasten the guard to the conveyor structure. It appears that one of the primary differences is whether or not a tool is required to remove the guard.

Fasteners must withstand the vibration, shock, and wear they are subjected to during normal operations. The various United States standards do not require guards to be secured on all sides, to be immovable, or to be removable only with the aid of tools.

Some guards are heavy or large enough—or designed and installed in such a way—they can remain in position without benefit of fasteners. For example, guards may be hinged at the top or side, hung, or rested in place, so they can be swung open or out of the way to allow for maintenance of the equipment they are guarding when it is properly shut down and locked out.

Figure 10.15.

A variety of fasteners can be used to hold guards in position, including bolts with a lockable integral wedge.

According to MSHA, hinged, hanging, or sliding guards do not require the use of additional fasteners if they are properly maintained, remain in their intended protective place, and stay closed. Similarly, guards may be suspended from, or rest on, tracks so they can be slid open or out of the way for maintenance of the equipment.

In Europe, section 1.4.2.1 of *Machinery Directive 2006/42/EC* requires that guards must be incapable of remaining in place without their fixings.

It might be suspected the intention here is to prevent a guard from being returned to position but left unfastened. In that case, it might be easily dislodged from its position, with the result it would not provide adequate protection. However, the requirement can create confusion for both guarding suppliers and plant operators. These requirements drew the criticism from at least one guarding manufacturer. Jeremy Procter, writing in Procter Machine Guarding's *Guide to the New Machinery Directive 2006/42/EC* noted:

> Roof panels and other horizontal panels will therefore bizarrely appear to need fitting with springs or some other means of preventing them from remaining in place when the fixings are removed.

Fasteners and the Need for a Tool

The question of just how guards should be fastened and removed is one subject of disagreement in the standards from various jurisdictions. Some agencies require the use of tools for guard removal; others—most notably MSHA in the United States—do not.

The 'tool for removal' requirement—which generally precludes the use of wing nuts, pin and sleeve closures, latches, hasps, magnets, and hooks-and-eyes—is designed to prevent unauthorized removal or adjustment of fixed guards. A reason cited for requiring a tool for guard removal is to emphasize that a device is a guard, performing a worker-safety function, rather than just a 'cover,' with the mission of merely keeping the process 'in' and dirt or environmental conditions 'out.'

In those standards that require a tool, there are differences about the nature of that tool and of the fasteners, with the standards specifying that the tool not be typically available to operators for use in the fulfillment of their conventional tasks. The requirement for special tools creates issues with even the use of slotted screws. Slotted screws would not be compliant because they can be undone using improvised tools such as a steel rule, coin, or even a fingernail, which would be easily available to an operator.

REGULATIONS AND STANDARDS Regarding Tool Use

Various jurisdictions have different regulations for guarding fasteners and tool-use requirements.

Australia

Australia's general standard on machine guarding, *AS/NZS 4024.1601-2014 Safety of machinery Part 1601 Design of controls, interlocks and guarding*, specifies in clause 5.4.3 that the removable parts of guards should be removable only by the use of a tool. The standard then refers to clause 3.9, where it explains tools would include a key or a wrench but not a coin or nail file or other such improvised tool.

The need to use a tool is echoed in the conveyor standard, *AS/NZS 4024.3610*. Here, clause 2.13.3.3(c) notes that if access to the danger zone would only be during planned outages, a removable guard that is not interlocked to the controls may be used. It further notes this guard should only be altered or removed by the use of a tool, and then refers to clause 2.13.3.6.

In clause 2.13.3.6, *AS/NZS 4024.3610* offers a similar statement, noting removable guards that are not interlocked with the system controls shall only be removable using tools available to competent personnel.

A parallel statement is provided in clause 1.5.32 of the *AS/NZS 4024.3610* standard, which describes a readily removable guard as requiring tools only available to competent persons.

In those standards, a competent person is seen as one who—through experience, education, and training—has the skills and knowledge to properly perform the identified work.

Western Australia's *Mines Safety and Inspection Regulations 1995* notes in regulation 6.2(2) that the plant is "to be maintained and operated in a safe manner" with consideration given to the following methods of risk reduction:

> (f) ensuring that any guarding provided for plant and its operation comprises
> …
> (iii) a physical barrier securely fixed in position by means of fasteners or other suitable devices, sufficient to ensure that the guard cannot be altered or removed without the aid of a tool or key.

Canada

The 2003 publication, *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*, jointly produced by Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) and Commission des normes, de l'équité, de la santé et de la sécurité du travail (CNESST), both of Quebec, notes:

> A fixed guard is a guard that can be removed only by using a tool or that is permanently set in place, for instance, by welding (Regulation Respecting Occupational Health and Safety, section 174).

Europe

Machinery Directive 2006/42/EC was written to harmonize standards and establish the regulatory foundation for health and safety requirements of machinery throughout the European Union. Section 1.4.2.1 of that directive includes the requirements for both tool use and captive fasteners on guards, stating:

> Fixed guards must be fixed by systems that can be opened or removed only with tools.
>
> Their fixing systems must remain attached to the guards or to the machinery when the guards are removed.

In a 2009 article, "Machine guard fastening and the new Directive," John Snyder, a product manager for a hardware supplier noted:

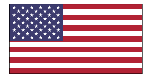
> Available designs include captive assemblies that fasten conveniently by hand but enhance safety by requiring a tool to release. … To address the tool-only access requirements of the new directive, head styles can include Philips, Torx, tamper-resistant, or industry-standard tool driver styles.

He further noted:

> One limitation of using captive screws is that ease-of-access can be variable—often determined by how tightly the user fastens the screw. In addition, when multiple fasteners are used or when the guard is accessed regularly, the time required to fasten conventional screws can render such arrangements somewhat cumbersome. Where speed and ease-of-use are of higher priority, other designs offer increased convenience at lower installed cost. These include fast-lead screws and quick-access quarter-turn fixing systems.

Jeremy Procter, in a 2013 posting, "On Your Guard," on Health & Safety Matters website, *hsmsearch.com*, wrote:

> Regarding the use of a tool, fasteners with a straight slot are inappropriate because they can be removed using improvised tools such as coins and rulers. Fasteners requiring spanners, cross-head screwdrivers or hexagonal (Allen) keys are generally acceptable.



United States

In its 2007 publication, *Safeguarding Equipment and Protecting Employees from Amputations*, OSHA notes, "Guards typically are designed with screws, bolts and lock fasteners and usually a tool is necessary to unfasten and remove them." On the other hand, *ASME B20.1-2015 Safety Standard for Conveyors and Related Equipment* makes no reference to guard locks or tool use for guard removal.

OSHA regulations in *29 CFR 1910.217(c)(2)(i)(d)* specify that point-of-operation guards "shall utilize fasteners not readily removable by operator, so as to minimize the possibility of misuse or removal of essential parts."

Fasteners that need tools for removal are not required by MSHA. Speaker notes provided with MSHA's 2010 PowerPoint presentation, *Guarding Conveyor Belts at Metal & Nonmetal Mines*, offer:

> Neither locks nor tools are required on fasteners to achieve compliance. However, the use of a lock or the necessity to use a tool to remove a guard does reduce the risk of injury.

Acceptable fasteners include bolted-on clamps, pin and sleeve connections, and various types of cotter pins.

The Need for Captive Fasteners

Some international standards have additional requirements for guard fasteners. European standards including *EN 620* paragraph 5.1.1.1, *EN 953* paragraph 5.4.3, and the *Machinery Directive 2006/42/EC* section 1.4.2.1 all require the attachment methods remain attached to the guards or to the machinery when the guards are removed.

According to the article, *Review: New Version of BS EN 953, Machine Guarding*, by Jeremy

Procter, the standard *BS EN 953* spells it out this way:

> 7.2 Retained fastenings
> Where it is foreseen (e.g. maintenance) that the fixed guard will be removed then the fastenings shall remain attached to the guard or to the machinery.

This requirement is also included in *EN 953*'s replacement, *BS EN ISO 14120* (section 5.19).

This approach simplifies reinstallation and eliminates the chance that fasteners can become lost and thus interfere with the security of a guard's installation or reinstallation.

The IRSST/CNESST publication, *A User's Guide to Conveyor Belt Safety: Production from Danger Zones*, notes: "Fasteners should remain permanently connected to the guards ('captive fasteners')." The publication then goes on to provide the additional explanation, "This precaution prevents the loss of fasteners and the need to replace them."

Cable Ties as Fasteners

In the United States, MSHA accepts cable ties as suitable for securing a guard in position providing they are maintained—that is, replaced when worn or damaged. These plastic fasteners—also known as zip ties, zip strips, tie wraps, cable ties, or wire ties—are commonly used for bunching and organizing wires. The authors recommend that plastic ties not be used as a fastener because they are subject to abuse and degradation.

In *Guarding Conveyor Belts at Metal & Nonmetal Mines*, a 2010 PowerPoint presentation provided as a compliance assistance resource, MSHA further explains:

> [Wire ties] are substantial and durable, easy to install, convenient for repairs and are not a hazard. They usually need the use of a tool to remove them, hence decreasing the risk that a guard could be inadvertently removed from its location or service. Like other guards, guard materials and fasteners, plastic wire ties must be maintained in a serviceable condition.

It should be noted that given enough time, cable ties may become brittle and break.

In Canada, cable ties are acceptable for securing a guard as the tie will require a tool—for example, side snip pliers—for removal. (**Figure 10.16.**)

In Australia, a plastic cable tie is not compliant with the requirements for fasteners, as the ties can be removed with a knife or simply broken by inserting a rod and twisting; that is, by items commonly available to an operator.

It should be noted that cable ties come in a wide range of sizes and specifications. Many may not be of suitable strength, resistance to the environment, or endurance for use as a guard fastener. Therefore, the authors recommend against this practice.

Keeping Your Distance

An effective design means that workers cannot defeat or otherwise circumvent the protection afforded by the fixed guard by reaching the hazard zone(s) with any part of their bodies. If a device can be bypassed, human nature tells us that—at some point—it will be; therefore, that device is not effective as a guard.

Effective fixed guards should be absolute in their protection—workers should not be

Figure 10.16.

Guard fasteners that use cable ties for added security need a tool for removal.

2

able to reach around, under, through, or over fixed guards to reach the dangerous moving parts of the machine. This has been called the A.U.T.O. Principle, from the acronym formed from the first letters of Around, Under, Through, and Over. (**Figure 10.17.**)

Reaching Over a Guard

Some standards provide safety distances for a range of panel heights in relation to the position of the hazard for a 'Reaching Over' situation. In some standards, the tables vary for low-risk and high-risk situations. (**Figure 10.18.**)

A number of standards, including the Australian/New Zealand standard *AS/NZS 4024.1801* in Table 1, Canada's *CSA Z432 (R2014)* in Table C-2, and Europe's *EN ISO 13857* in Table 2, use the following dimensions for barriers:

A.U.T.O.

Fixed barrier guards must be designed to prevent access to danger areas by reaching

A round

U under

T hrough or

O ver

Figure 10.17.

The acronym A.U.T.O. provides a guide to the duties of a guard: preventing access Around, Under, Through, or Over.

Figure 10.18.

A proper guard will keep workers from reaching the hazards of a conveyor.

Image courtesy of the United States Mine Rescue Association.

- Vertical barriers less than 1,000 mm [≈40 in.] tall are not effective regardless of distance from hazard.
- Barriers less than 1,400 mm [≈55 in.] should not be used without additional safety measures.

In some cases, smaller distances to the hazard may be allowed if the barrier is taller; consult the appropriate regional standard.

Reaching Under a Guard

Where moving-part hazards exist close to floor level, the need to protect and restrict personnel will override the need to clean up spillage. Consequently, there are limitations on the opening from the floor to the bottom of a guard. The scenario of someone lying on the floor and reaching in under a guard to retrieve a dropped tool or other article and coming into contact with a pinch point provides an example of why this area needs to be restricted.

Reaching Through a Guard

Preventing reaching through a guard to the hazard presents a challenge as many types of barrier guarding are usually made of expanded mesh or a similar material. In order to ensure that openings are not so large they allow access to the hazards, a number of standards have been created. The standards spell out the distances, heights, and clearances that are allowed (or required), in order to preclude the possibility of worker encroachment into the hazard zone. The standards are used to determine guard mounting distances based on the maximum opening sizes in the guarding. Compliance ensures that any body part which can fit through the mesh will not be able to reach the hazardous moving parts within.

The size of the openings in the guard must be checked to make sure they will keep worker extremities out of harm's way. Most international jurisdictions offer a standard that identifies the size of the holes needed at a specified distance from a hazard. Basically, the larger the opening, the further the guard needs to be from the hazard.

Setting the Standard for the Size of Openings

As far back as the 1940s, researchers looked to specify a minimum safe distance from a hazard to a guard opening, as based on the size of an average worker's hands and arms. This research is variously attributed to Liberty Mutual Company and/or the National Association of Mutual Casualty Companies (NAMCC). The resulting dimensions were eventually incorporated into the 1971 revision of the *ANSI B11.1* safety standard for mechanical power presses. OSHA used the ANSI document as the basis for its own mechanical power press standard, *29 CFR 1910.217*, also published in 1971. Thus the dimensions in Table O-10 in the OSHA regulations—and the related 'gotcha stick' safety ruler—are rooted in the 1949 NAMCC publication, *Safe Openings for Some Point of Operation Guards*. (**Figure 10.19.**)

While originally specified for mechanical power presses *29 CFR 1910.217*, Table O-10 has been applied to other guarding situations, perhaps due to a lack of other guarding specifications with detailed measurements.

In a 1995 report, "A Review of Machine-Guarding Recommendations," Donald Vaillancourt and Stover Snook of the Liberty Mutual Research Center for Safety and Health, compared data from six more recent anthropometric surveys to determine if the dimensions in Table O-10 needed updating. Their report, published in *Applied Ergonomics*, provided a revised table of recommended guard openings-versus-distance measurements. While the OSHA Table O-10 has 10 'stair steps' in the size of openings, the Vaillancourt and Snook report shows only six. While not officially adopted by OSHA, the Vaillancourt and Snook measurements have been adopted by a variety of other machine-safeguarding standards.

Unfortunately, the needs of bulk-material handling make impractical some of the machine tool-based requirements for opening size and distance. The smaller openings in machine guarding may, when applied in bulk handling, actually reduce safety by accumulating fugitive material and thus restrict the ability to inspect or clean. The 'blinding' of these screens with material then creates a motivation to remove the guard, and the opportunity for purposefully or inadvertently failing to replace the guard, exposing the hazard. Guards for bulk-materials-handling systems may well

Table O-10: Maximum Allowable Guard Openings

Distance of Opening from Point of Operating Hazard mm [in.]	**Maximum Width of Opening** mm [in.]
0–13 [0–0.5]	No Opening Allowed
13–38 [0.5–1.5]	6.3 [0.25]
39–64 [1.5–2.5]	9.7 [0.38]
64–89 [2.5–3.5]	13 [0.5]
89–140 [3.5–5.5]	16 [0.63]
140–165 [5.5–6.5]	19 [0.75]
165–191 [6.5–7.5]	22 [0.88]
191–318 [7.5–12.5]	32 [1.25]
318–394 [12.5–15.5]	38 [1.5]
394–445 [15.5–17.5]	48 [1.88]
445–800 [17.5–31.5]	54 [2.13]
Over 800 [31.5]	152 [6]

Figure 10.19.

Maximum Allowable Guard Openings as presented in Table O-10 from OSHA regulation OSHA 29 CFR 1910.217.

be able to assure safety with fewer levels of required distances.

The 'Gotcha Stick'

The required distance from hazards shown in United States' OSHA Table O-10 is reflected in the 'safety rulers' used to check guard installations. (**Figure 10.20.**) Sometimes called a 'gotcha stick,' these rulers are used during the design, installation, and inspection of barrier guards to verify compliance with *OSHA 29 CFR 1910.217*, Table O-10. (There are now updated versions of these specialty rulers that coincide with Vaillancourt and Snook's research cited above.)

Figure 10.20.

A 'gotcha stick' provides a method to check the size of the mesh in a guard against the required distance from a hazard.

The rulers are based on the measurements of parts of the human body, representing the finger, hand, and arm. (**Figure 10.21.**) Inserting this ruler through the openings in a guard provides a simple gauge of compliance or non-compliance with the measurements expressed in Table O-10. These rulers are used by plant safety personnel, guarding installation crews, and safety inspectors alike to check proper installation. If, when pushed through the opening in the guard, the ruler touches the hazard, the guard is not in compliance.

A number of guarding manufacturers and safety supply houses offer versions of this ruler. These rulers are typically designed to fold to improve portability and ease of use, and are available in aluminum or plastic. (**Figure 10.22.**)

As mentioned above, there are limitations in the application of Table O-10—and thus with the use of the 'gotcha stick'—in determining

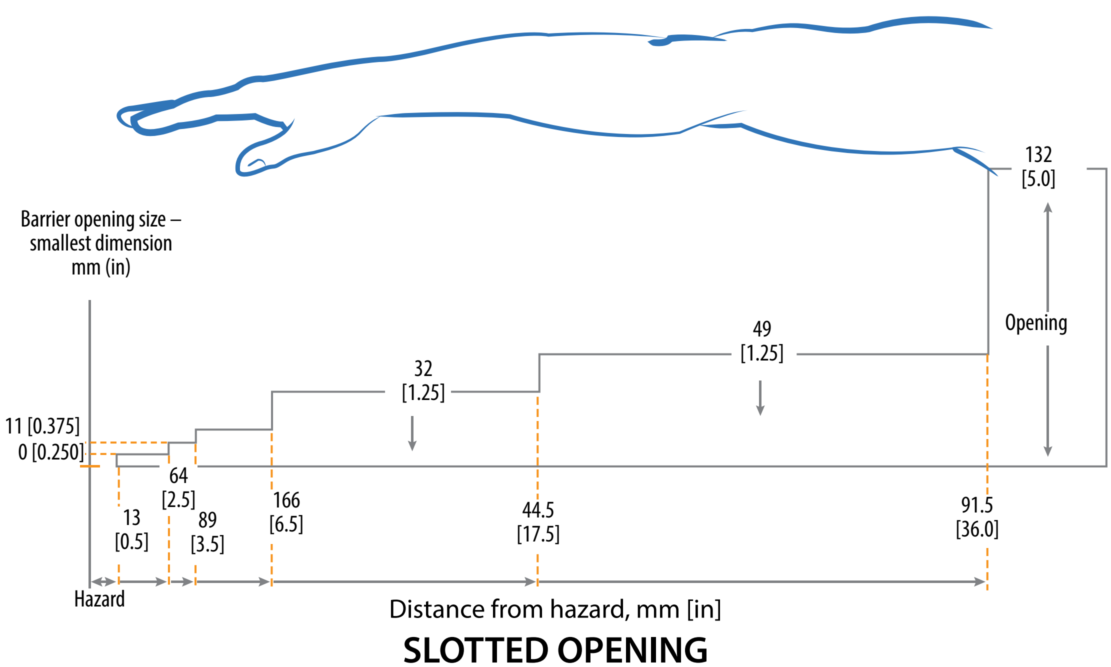


Figure 10.21.

Safety rulers are designed using typical dimensions of human anatomy, providing a gauge of compliance with the dimension as specified in Table O-10.

proper guarding for bulk-material-handling belt conveyors.

The Use of Pre-Engineered Guard Panels

A number of suppliers offer pre-engineered guarding systems. Typically, these guards consist of metal panels that have been punched, burned, or otherwise fabricated to create a guard with an open mesh that provides a protective barrier yet allows inspection. (**Figure 10.23.**) The panels may be hung in or on a frame, or self-supporting to be attached on or near the conveyor structure.

Handles may be offered either as bent-out sections integrated in the frame or as attachable options. The panels typically feature pre-drilled mounting holes, and most suppliers offer one or more variations of fastener.

These pre-engineered guard panels are typically available as rectangles of various sizes, from perhaps 24 by 24 inches to 36 by 50 inches [≈610 by 610 mm to ≈915 by 1,270 mm]. In most cases, the guards can be customized during installation to fit variations in machinery design or openings of unusual size or configuration.

These manufactured guard panels are generally available with the openings in the mesh in one or two given sizes per manufacturer. This mesh size will have been selected by the manufacturer for reasons of standardization and/or ease of manufacturing and will typically comply with Table O-10 and/or other guarding standards for a typical installation.

This means the guard panels from a given manufacturer should be installed at the coinciding distance from the hazard. In most cases, this is achievable, but it does call for care on the part of the installation crew to make sure the panel is installed at the proper distance and then adequately reinforced. Shims or other supplemental supports may be required to push the guard panel out to the proper distance from the hazard.

A Simplified Approach for Conveyor Guards

There is little information available to assist in designing guards that comply with standards. This section will attempt to provide engineering and fabrication direction for the design and construction of guards to be used on belt conveyors handling bulk materials.

The chief concerns in the application of guards on belt conveyors are: first, to provide a physical barrier from accidental contact and second, to allow as much inspection and observation as reasonably possible of the conveyor components and cargo without removing the guard.

As has been noted earlier in this chapter, distance to hazard guards based on OSHA's Table O-10 and the 'gotcha stick' are not well suited for adaptation on bulk-materials-handling conveyors. The dimensions in Table O-10 were developed to safeguard operators as young as 14 years of age who are standing at a mechanical press, frequently inserting and removing stock by hand during a full work shift.

The openings in guard meshes established with the 'gotcha stick' are generally too small. These

Figure 10.22.

A 'gotcha stick' is usually designed to fold for portability and ease of use.

Figure 10.23.

Pre-engineered guard panels in a variety of sizes can be installed to fit the situation.

openings can fill up with fugitive material making inspection of belt conveyor components difficult. Using different mounting distances for every mesh opening or hazard type increases the likelihood that guards for conveyors will be misdesigned.

Even as *ISO 13853:1998* specified the distances required with 'gotcha stick' measurements, it disclaimed them, saying in its Scope statement:

> For certain applications, there are justifiable reasons to deviate from these distances. Standards dealing with these applications should indicate how adequate safety can be achieved.

The same disclaimer appears in several other standards, notably Australia's *AS/NZS 4024.1801-2006 Safety distances to prevent danger zones being reached by the upper limbs* and Japan's *JIS B 9711 Safety of machinery – Minimum gaps to avoid crushing of parts of the human body*.

Some standards such as MSHA regulations in the United States in *CFR 30 56/57.14107* through *56/57.14112* provide general requirements for guards but very few specific dimensions or values. As noted previously in this chapter, the MSHA regulations state only that the guard should be constructed and maintained so they will not create a hazard, are held securely in place while the machinery is in operation, and will withstand shock, vibration, and wear to which they will be subjected to during normal operations.

European Norm *EN 620* states in section 5.1.1.1 that where guards can be stepped upon:

> They shall be able to withstand a force of 1,500 N [≈337 lb_f] evenly distributed over an area of 0.2 x 0.2 m [≈ 7.9 x 7.9 in.] with permanent deformation of less than 1% of any reference dimension and no contact with any moving part.

The Australian/New Zealand standard *AS/NZS 4024.3610* includes a number of specific guidelines for guard construction. In clause 2.13.4.3, it notes that the minimum thickness for sheet steel guards should be 1.5 millimeters [≈0.06 in]. Mesh guards with a 50 x 50 millimeter [≈2 by 2 in.] mesh should be made of wire not less than 1.5 millimeter [≈0.06 in.] or 3 millimeters [≈0.12 in.] in diameter.

In clause 2.13.4.4 Guarding strength, the standard requires safety distances shall be maintained when a force of 450 newtons [≈101 lb_f] is applied over an area of 50 x 50 millimeter [≈2 by 2 in.] at any point on the guard. For guards that can be rested or climbed upon, the guard must resist a mass of 900 newtons [≈203 lb_f] and a simultaneous horizontal load of 220 newtons [≈49.5 lb_f] and maintain the required safe distances.

In addition, clause 2.13.4.5 states that for square mesh openings up to and including 10 millimeters [≈0.4 in.], the guard must be at least 25 millimeters [≈1 in.]; meshes with openings up to 30 by 65 millimeters [≈1.18 by 2.5 in.] should be placed 200 millimeters [≈7.87 in.] from the hazard.

This standard will accommodate the need to prevent occasional and accidental contact with conveyor hazards with the need to inspect both conveyor components and cargo.

A Proposal to Standardize

The combination of types of hazards, size and location of equipment, and the possible designs of guards to protect against any one hazard is incalculable and will invariably lead to differences of opinion between operators and government inspectors.

To simplify fabrication and comply with the intent of guarding bulk-materials-handling conveyors, a better practice would be for the conveyor industry to standardize with a limited number of types and sizes of mesh and standard distances from the hazards. Rather than using the machine tool-based dimensions specified in Table O-10, the time has come to adopt a revised conveyor guard standard established to meet the needs and circumstances of belt conveyors.

The intent here is to provide a simplified design approach for the strength of guard panels which is reasonable for the intended purpose of preventing accidental contact with a hazard under the loads stated in the standards. (**Figure 10.24.**)

This proposal would standardize guards as constructed in five different configurations: woven wire mesh with two sizes of openings, a welded wire in a larger size mesh, chain link fencing, and laser-cut sheet metal. Each of these different mesh materials would be matched to and installed at a specified standardized distance from the hazard to provide an effective guard and simplify construction and compliance.

To achieve these standard mounting distances from the conveyor nip points might require shims or building out the framework. But the effort would be worth it through the improvement of guarding practices, as well as the standardization of guard materials and the simplification of inspection and regulatory enforcement. This approach also lends itself to modular structural construction for standardization of guard mounting.

As noted in **Testing the Strength of Guarding**, guards from these specified materials will be strong enough to withstand the force applied by a worker who accidentally runs or falls onto the guard. No 'gotcha stick' measurement or standardized guarding program can prevent deliberately defeating a guard. When installed at the specified distance from the hazards, the openings in the guard will keep worker appendages a reasonable distance away from hazards common to bulk-materials handling by conveyor belt.

Design of Frames for 'New Standard' Guard Panels

The guard panels can be floating or fixed in design. A floating guard panel is a self-supporting mesh and frame or sheet metal plate construction that is mounted loosely on pins or studs.

Floating guard panels are often used where guards must be removed or opened frequently. A fixed guard panel is designed to be attached to a fixed structure and utilizes multiple attachment points to resist the design forces.

Mesh Selection

Nominal Guard Mesh	Mounting Distance from Hazard	Typical Applications
Woven Wire Mesh 12.7 x 12.7 x 2 mm [≈½ x ½ x 0.08 in.] wire	50 mm [≈2 in.]	Couplings, belt and chain drives, guard area of less than 0.5 m^2 [≈5.38 ft^2]
Flattened Expanded Metal 13-Guage 12.7 x 12.7 x 2 mm [≈1/2 x 1/2 x 1/25 in.]	50 mm [≈2 in.]	Couplings, belt and chain drives, guard area of less than 0.5 m^2 [≈5.38 ft^2]
Welded Wire Mesh 2 x 2 x 0.12 or 0.16 in. [≈50 x 50 x 3 or 4 mm] wire	200 mm [≈8 in.]	General area guarding, barrier guards on idlers and pulleys, guard area of less than 0.5 m^2 [≈5.38 ft^2]
Laser-Cut Sheet Metal Guard 11-gauge	200 mm [≈8 in.]	Floating guard panels designed for frequent removal, guard area of less than 0.5 m^2 [≈5.38 ft^2]
Chain Link Fence 9-gauge woven fabric 2 x 2 in. normal size [4 mm wire, 50 x 50 mm normal size]	500 mm [≈20 in.]	Falling material guards up to 200 mm [≈8 in. in any dimension] minus nominal bulk material size. Use 6-gauge wire for larger lump sizes.

Figure 10.24.

Suggested standard guard mesh and mounting distance for typical conveyor applications.

In contrast, fixed guard panels are used where access is required infrequently or to reduce the chance of unauthorized removal.

Floating guard panels can be made of laser-cut sheet metal or mesh material attached to a frame.

The frame of the floating guard panel must be strong enough to resist bending and retain its intended shape. A hinged guard should be designed as a floating panel. Typical construction would be an angle iron or flat bar frame with the mesh welded to the frame at frequent intervals, for example, every 50 millimeters [≈2 in.]

Floating guard panels require some type of retaining means to the pins or studs such as

Testing the Strength of Guarding

There is little information available to assist in designing guards that comply with standards. This section will attempt to provide engineering and fabrication direction for the design and construction of guards to be used on the belt conveyors handling bulk materials.

To evaluate the guarding scheme proposed—and the guards that would result from it—a testing program was developed and sample guards were constructed and subjected to both computer-based Finite Element Modeling (FEM) and physical testing.

Finite Element Method

The modeling of specific guards can be very complex and impractical as almost every guard is a custom shape and local availability of mesh materials varies. As a result, it was determined to perform Finite Element Method analysis of material performance using standard 1 meter [≈39 in.] square panels and do physical testing on 36 inch [≈914 mm] square panels.

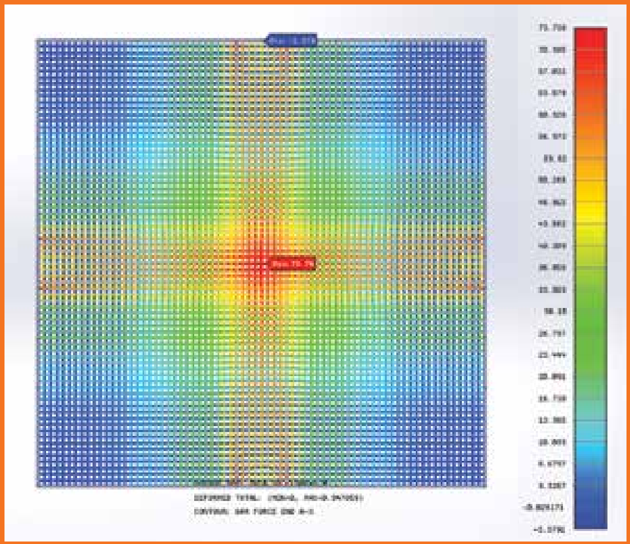


Figure 1.
FEM model showing predicted deflection under load.

To determine deflection under load, the various guard materials were modeled using FEM software. The modeling would predict the deflections under load for a standard 1 meter [≈39 in.] square panel. (**Figure 1.**)

The FEM indicated that if a guard panel frame is restrained (with mounting fasteners) at approximately 250 millimeters [≈9.8 in.] spacing, the frame material has little influence on deflections and the guard panel mimics a flat plate. When the mounting is only in the four corners of the guard, the frame deflection has some influence but not significant if the cross-sectional area of the frame is sufficient to act as a fixed mounting.

Physical Testing

To confirm the validity of the FEM models, physical testing of the sample guard panels was conducted using the loads specified in the European and Australian standards.

Figure 2.

Test method for concentrated load on flattened expanded metal panel.

In the testing procedure, 36 inch [≈914 mm] square guard samples were mounted to a 2 x 2 x ¼ inch [≈50 x 50 x 6 mm] angle iron frame with fasteners spaced at approximately 8 inch [≈203 mm] intervals. Using a mandrel suspended from an overhead trolley and chain hoist, concentrated loads were hitch pins, padlocks or threaded fasteners. The openings to attach the floating guard panel or frame to the structure are often oversize for easy removal and replacement and are, therefore, often only located in the corners of the panel.

A fixed guard panel frame utilizing the same guard mesh as a floating panel can be of lighter construction, as the resistance to bending is accomplished by the guard's semi-permanent attachment to a structure. The mesh material is typically welded to the frame, which is drilled at regular intervals to accept threaded fasteners. The semi-permanent attachment to a substructure helps direct the forces in line with the mesh, reducing the tendency for the frame to deflect. (**Figure 10.25.**)

applied on a 2 x 2 inch [≈50 x 50 mm] area. The mandrel weighed 16 pounds force [≈71 N] and concrete weights of approximately 48 pounds force [≈200 N] each were used to increase the loading. Loading was done with 1 to 5 weights providing a force up to a cumulative 300 pounds force [≈1,334 N]. (**Figure 2.**)

Measurements were made using a caliper before applying the load and under load. (**Figure 3.**)

As would be expected, when the load was distributed on the panel over the contact area (0.79 ft^2) [≈0.07 m^2] of the test weights, the deflection was less than that produced by point loading. (**Figure 4.**)

As shown in the following illustration, results of the physical testing indicate maximum deflections vary by the type of material used in guard construction. (**Figure 5.**) Maximum deflection was the smallest with the welded wire mesh and greatest with the chain link fence fabric.

Permanent deflection was recorded as the difference between the reading before test load was applied and the final deformation after removing the final 300 pounds force [≈1,334 N] load. These loadings provide a reasonable reflection of the loading in the standards, which range from 450 to 1,500 N [≈101 to 337 lb_f].

There was some permanent deflection measured on all of the guard panels, with chain link fabric exhibiting the greatest permanent deflection. This was a result of the difficulty of applying the load on more than one wire strand due to the weave pattern of chain link fence. When a distributed load was applied to the chain link fabric, the temporary deflection behavior was similar to the other guard panels.

Figure 3.

Measurement method on flattened expanded metal panel before loading.

Figure 4.

Test method for point load on flattened expanded metal panel.

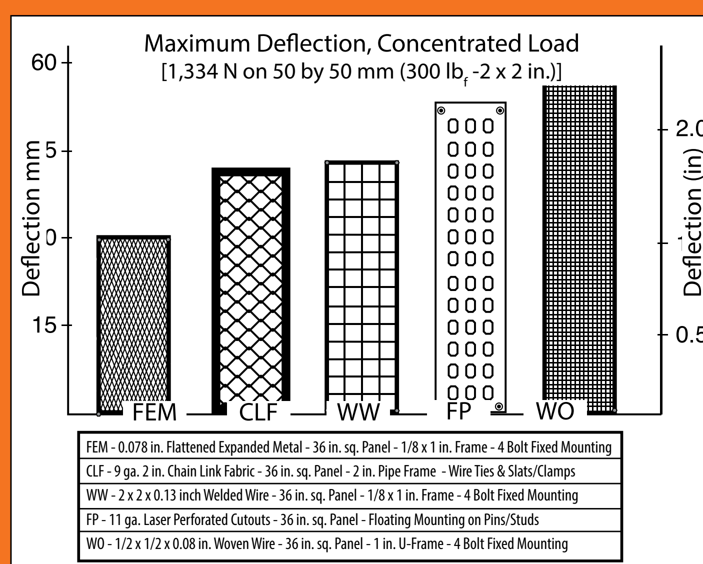


Figure 5.

Maximum deflection for various guard materials under concentrated load.

Typical frame materials are U-channels, which cover the sharp edges of expanded metal or steel flats. Preformed U-channels are available from steel service centers that sell expanded metals and woven wire meshes. (**Figure 10.26.**)

The loads applied to the mesh under the standards are quite low for most frame cross sections. Standard beam deflection formulas and moments of inertia for common structural shapes can be used to design frames.

On the Use of Chain Link in Guards

Guard panel frames utilizing chain link fencing are usually made with pipe as there is a wide variety of fittings and attachments available for chain link. Chain link fabric can also be easily adapted to other structural frames.

The loading described in the standards is for accidental contact by a worker and not for the accumulation of spillage. When chain link fence is used for spillage protection, the potential loads must be considered in selection of the fabric wire size, the forces applied to the attachment method, and frame.

The intent in recommending chain link fence is for use as falling material nets and fencing for area guarding. Chain link fence is different in that the attachment method to the pipe frame involves stretching the fabric and using slat bars and binding wires. This leaves a great deal of variation in fabric tension. The Chain Link Manufacturers Institute could offer no guidance on the use of chain link fabric for guarding beyond its standard approach, which is to limit the applied load so that the breaking strength of a single strand is not exceeded. For 9-gauge wire, the required breaking strength of chain link steel wire is specified as 1,290 pounds force [≈5,740 N], as specified in the *Chain Link Fence Manufacturers Institute Product Manual CLF-PM0610*. This is significantly below the loading used in the designing guards, but must be considered when chain link fabric is used to capture and retain spillage.

2

Figure 10.25.

Recommended materials for floating frame guards on belt conveyors.

Recommended Materials for Floating Frame Guards on Belt Conveyors

Guard Largest Dimension	Typical Minimum Floating Frame Material
≤ 1 m [≈3 ft]	38 mm x 5 mm [≈1½ x 3⁄16 in.] steel flat, 10-gauge [≈3 mm] sheet metal, or 38 x 38 x 3 mm [≈1½ x 1½ x ⅛ in.] angle iron.
≥ 1 m [≈3 ft]	50 mm x 6 mm [≈2 x ¼ in.] steel flat, 5 mm [≈3⁄16 in.] steel plate, 50 x 50 x 6 mm [≈2 x 2 x ¼ in.] angle iron, or 2 inch [≈50 mm] schedule 40 pipe.

Figure 10.26.

Recommended materials for fixed frame guards on belt conveyors.

Recommended Materials for Fixed Frame Guards on Belt Conveyors

Guard Largest Dimension	Typical Minimum Fixed Frame Material
≤ 1 m [≈3 ft]	25 mm [≈1 in.] flat U-channel, 25 mm x 3 mm [≈1 in. x ⅛ in.] flat, or 10-gauge [≈3 mm] sheet metal.
≥ 1 m [≈3 ft]	38 x 6 mm [≈1.5 in. x ¼ in.] flat, 38 x 38 x 5 mm [≈ 1½ x 1½ x 3⁄16 in.] angle iron, or 2 inch [≈50 mm] schedule 40 pipe.

A New Age of Guarding

As noted in *MSHA's Guide to Equipment Guarding*, several new technologies show promise as advanced guarding systems; they include:

Proximity Sensors

Proximity sensors have been proven to reduce accidents in underground mining, particularly at the face where visibility and noise issues reduce the equipment opera-

Formulas to Match the Test Findings

The approach for recommended frame materials is to assume that the guards will be freely hung and the frame acts as the fixed structure. The structure upon which the guard panel is hung must have sufficient capacity to limit deflection in any direction to the commonly used requirement of less than one percent.

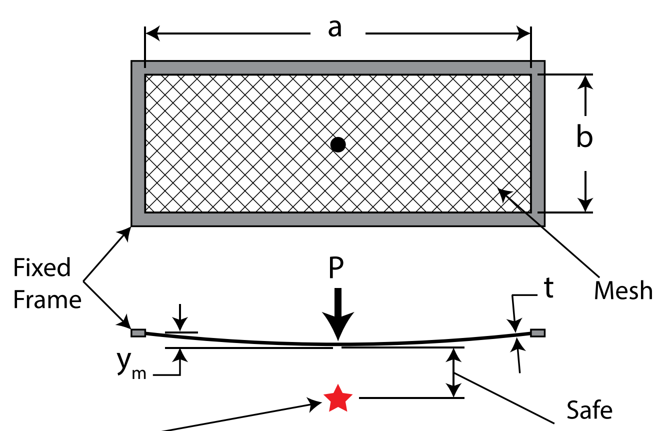
Comparing the results of FEM analysis and the physical testing, it is reasonable to apply the equations for fixed flat plate deflection to the suggested guard materials. (**Figure 1.**)

As shown in both the FEM and physical testing, the deflection of the 1 inch x 0.13 inch [≈25 x 3 mm] flat frame and 18-gauge (≈0.05 in.) [≈1.2 mm] thick 1 inch [≈25 mm] U-channel frames was minimal at the loads applied. This gives further support for assuming that the formulas for flat plates provide a reasonable approximation for deflection.

The equation is for rectangular plates with a concentrated load in the center where the deflection is expected to be equal to or less than the plate thickness. The physical test data and FEM results indicate an approximate linear relationship between load and deflection which was roughly parallel but offset (greater deflection) from the formula predictions even with deflections much larger than the mesh thickness.

Modifying the thickness,'t' of the mesh material was not as good a fit to the tested curve fit modifying the k_1 aspect ratio factor. The test data compared to the formula shows good agreement with a linear trend line fit if the k_1 factor is modified. Modifying the k_1 factor is basically the Y intercept. Therefore, the flat plate deflection formula using the modified aspect ratio k_1 factors as shown is proposed for a reasonable approximation for design purpose. (**Figure 2.**)

Modifying factor k_1 has the effect of adjusting for the Y offset. For critical applications it is recommended a test panel be built and tested under load to establish an appropriate k_1. In all cases the deflection difference between the formula and physical testing was not significant compared to the suggested mounting distances from the hazard as shown in the table.



$$y_m = k_1 \times \frac{P \times b^2}{E \times t^3} \text{ at Center}$$

y_m = Deflection (m), k_1 = Aspect Ration Factor,
P = Concentrated Load (N), a = Plate length (m)
b = Plate Width (m), E = Youngs Modulus (N/m²), t = Plate thickness (m)

Flat Rectangular Plate Clamped Edge Deflection Formula

Figure 1.

	Aspect Ratio a/b						
	1.0	1.2	1.4	1.6	1.8	2.0	≥ 3.0
Clamped Solid Steel Panel k_1	0.061	0.071	0.076	0.078	0.079	0.079	0.079
Floating Solid Steel Panel k_1	0.127	0.138	0.162	0.170	0.177	0.180	0.185

From *http://www.roymech.co.uk/Useful_Tables/Mechanics/Plates.html*

Figure 2.

tor's ability to react to other workers in the area. NIOSH is currently developing the technology that will work in combination with interlocked guards to make it more difficult for guard interlocks to be bypassed or guards to be closed when workers are still in a hazard area. (**See Chapter 4 Switches and Sensors.**)

Light Curtains
These devices are photoelectric sensors that project infrared light beams between a transmitter and a receiver. Whenever the transmission is broken—by a worker extending a hand inside the danger zone, for example—the device will remove motion and/or power from the hazardous equipment. Light curtains can protect personnel from injuries and can be used as an alternative to mechanical barriers and other forms of traditional machine guarding.

Pressure-Sensitive Floor Mats
These systems connect to the machine's power control and shut down the system when the weight of excessive spillage or a worker is on the mat. These mechanical pressure mats open electrical contacts to stop a motor when material accumulation indicates a production upset, or someone steps on the mat in (or approaching) a hazardous area

Advanced Interlock Systems
Interlock systems can now be offered with several zones or layers of protection. Multiple contacts or zones can be used to trigger a warning alarm for entry into an area and then shut down a system if the person continues past the warning and approaches a hazard too closely.

While new technologies may be suitable in some situations, there are pitfalls to be considered in systems that use these alternative guarding systems. *MSHA's Guide to Equipment Guarding* suggests the following types of questions be asked:

- Does the system react quickly and at sufficient distance to prevent contact with the moving parts before their motion has stopped?
- Is the system redundant?
- Can it be by-passed, such as ducking under a laser beam?
- Is there regular and frequent testing?
- Will the system fail safe?

The Future: Where Conveyor Guarding is Going

The increasing sophistication of plant controls and computer systems may require better methods to manage plant safety—including conveyor safety. As new conveyor systems are developed, and more tech-savvy employees come into the workplace, updated styles of guards may become more typical.

In a 2004 article, "Safeguarding: Future Trends in Machine Safeguarding," which is available on *ehstoday.com*, Joseph Lazzara presented some thoughts on the future of guarding. His list included the trends listed below; the discussion following each point represents a paraphrase of his thoughts as they translate to conveyor systems.

Trend: Mobility of Workforces

It is not unusual for workers in many industries to be transferred between operations in various countries. The trend is particularly common with technical and management personnel who often bring experiences which conflict with local practices. Even plant laborers often follow the work within their industry moving from country to country. Safety would be enhanced by global standards for safety.

Trend: Globalization of Standards

The trend for globalization and the rapid development of international standards for machine safety—including conveyers—will continue or accelerate. Presently, the United States is lagging—some might say fighting—the trend toward global harmonization of standards. In many instances, the European standards have served as the proving ground for the international standard bodies, such as the International Electrotechnical Commission (IEC). In other cases, the Australian standards are seen as the most rigorous and so represent the high-water mark to which all jurisdictions should move.

Trend: Earlier Integration of Safety in the Conveyor Design Cycle

The days of 'The conveyor is almost finished, let's throw some guards on it' are over. The risks and costs of injury and the increase in regulatory pressure call for the earlier integration of safety into the machine design cycle.

Clearly, the hazards and safety considerations of a machine should be and are being evaluated and mitigated earlier in the design cycle by use of a 'Prevention through Design' concept. With this trend, safety becomes an increasingly important consideration in the conveyor engineering sequence. (**See Chapter 31 Designing and Building Safer Conveyors.**)

It is important to appreciate that effective guarding incorporated at the design stage of a machine will be less expensive. Modification after a machine has been introduced may be technically difficult or even impracticable; it certainly will be more costly.

Incorporation of safety and guarding in equipment design offers other benefits too. An emphasis on safety in the engineering process provides improved accessibility as well as improved machine esthetics, which offer cleaner designs with better maintainability.

Trend: More Intelligent Safety Systems

The trend of more intelligent safety devices is a natural component of the evolution of conveyor guards. As new technologies are developed and alternative ways of protecting workers become available, their use could provide a level of protection surpassing conventional guarding.

Trend: More Formal Risk Assessments/ Risk-Reduction Processes

The next trend involves the use of more formal risk-assessment and risk-reduction programs. The performance of a formalized risk-assessment program will help ensure that belt conveyors and other machines are designed, operated, and maintained with the safety and integrity of the machine in mind at an early stage in the machine's development. This will also guide the application of guards to appropriate points on that equipment.

BEST PRACTICES

Design and Construction of Guards for Belt Conveyors:

1. Guards should not be designed to be walked or climbed upon. Either construct such guards as if they were walking/working surfaces (grating) or provide a crossover.
2. Guards that are hinged should take less than 75 newtons [≈16.9 lb_f] of force to open or close, requiring hinge and latch designs being corrosion- and dirt-resistant.
3. To allow inspection, the open area in the mesh should be 50 percent or more.
4. Fixed guard panels should be designed to be attached every 200 millimeters [≈8 in.]
5. Floating guard panels should be designed with a minimum of four mounting points, preferably in the corners.
6. Floating guard panels that are hung freely on a structure and designed for frequent removal should weigh less than 23 kilograms [≈50 lb].
7. 50 x 50 millimeter [≈2 x 2 in.] mesh guards should be located no closer than 200 millimeters [≈8 in.] from the hazard to be guarded.
8. Guard panels should have handles. Guard panels heavier than 23 kilograms (≈50

2

lb) should have lifting points for use with mechanical lifting aids.

9. 12.7 x 12.7 millimeter [≈½ x ½ in.] mesh or expanded metal guard panels should be located no closer than 50 millimeters [≈2 in.] from the hazard to be guarded.
10. Fasteners should be self-retaining or attached with lanyards so they are not lost when guards are removed. A tool is required for removal of any guard.
11. Frame corners should have a radius, and all sharp edges of the frame and/or mesh removed.
12. Where there are openings in the guard panel (for example, for lubrication access) they should be bordered with frame material to eliminate sharp edges.
13. Guard panels not built as described in this section should be tested for deflection before mounting to ensure that a safe distance from the hazard is maintained.
14. Guards utilizing electrical interlocks or remote noncontact sensing technology, such as RFID tags, should be tested for interference from other electrical signals. Guards so equipped should be tested monthly and a record of testing retained.

CLOSING THOUGHTS
Guarded Optimism

Proper conveyor guarding can ensure safe operation at all times and can give confidence to the operations and maintenance personnel who must work around these systems. Guards which are properly designed, installed, and maintained help increase the production capacity of the machine. The elimination of mechanical hazards by providing effective guarding is a positive gain to belt conveyors in particular and plant operations in general.

Clearly the trend in regulation and enforcement is to increase the number of locations on the conveyor that require guarding, with many world-class companies taking the position that the entire conveyor should be guarded. A forward-looking designer should consider modular conveyor designs that are amenable to full guarding with standardized and modular panels. ⚠

2

Chapter 11 The Myth of 'Guarded By Location'

INTRODUCTION

In industrial safety, 'guarding by location' is the concept where a hazard positioned at such a distance so that it is the beyond the reach of a worker is considered 'safe,' and so the hazard does not need to be otherwise guarded. (**Figure 11.1.**)

This phrase is used when discussing conveyor components, or with other types of moving machine parts, which when positioned closer to the worker, workplace, or walkway, would present a hazard.

In its Small Business Safety and Health Management Series online document, *Safeguarding Equipment and Protecting Workers from Amputations* (OSHA 3170-2001), the Occupational Safety and Health Administration (OSHA) in the United States defines 'guarding by location' as:

> positioning or designing a machine so that the hazardous parts are away from areas where employees work or walk, or

alternatively, installing enclosure walls or fences that restrict access to machines.

Overhead Hazards

'Guarding by location' creates what can be considered an exception to the general requirements for the guarding of hazards in the workplace.

"The American Society of Mechanical Engineers," (ASME) *B20.1-2015 Safety Standard for Conveyors and Related Equipment* notes in section 5.9.2(a), "Remoteness from frequent presence of public or employed personnel shall constitute guarding by location."

In its Definitions section, the ASME Safety Standard explains the concept of 'guarded by location,' noting the phrase:

> ... describes moving parts which are protected by their remoteness from the floor, platform, walkway or other working level or which by their location with reference to frame, foundation, or structure as to remove the foreseeable risk of accidental contact by people or objects. Remoteness from regular or frequent presence of public or employed personnel may, in reasonable circumstances, constitute guarding by location. Unprotected danger points and areas that are inaccessible to the operating personnel in the normal performance of their duties shall be considered guarded by location.

In its section 2.13.1 Safeguards: General, the Australian New Zealand standard *AS/NZS 4024.3610 Safety of Machinery – Conveyors – General requirements* uses much the same words as ASME to describe what it terms "guarded by location or position."

There are many hazard locations that are beyond the normal reach of a worker when working or walking under or around elevated conveyors. (**Figure 11.2.**) These hazards are often considered to be covered by the 'guarded by location' exception; they are often in-running nip points between the belt and return rollers or drive components such as pulley shafts, couplings, drive belts, gears, and chains.

REGULATIONS AND STANDARDS

Regulations often specify a specific distance beyond which a hazard would be considered 'guarded by location,' and so would not need conventional barrier guards. Regulations in some jurisdictions specify the hazard is at least 2.1 meters [≈7 ft] from the work or walking surface; other regulations have greater test distances.

Australia

AS/NZS 4024.3610 discusses guarding by location in section 2.13.1 Safe-

Figure 11.1.

The phrase 'guarded by location' is used to discuss conveyor components which would present a hazard if positioned closer to the worker, workplace, or walkway.

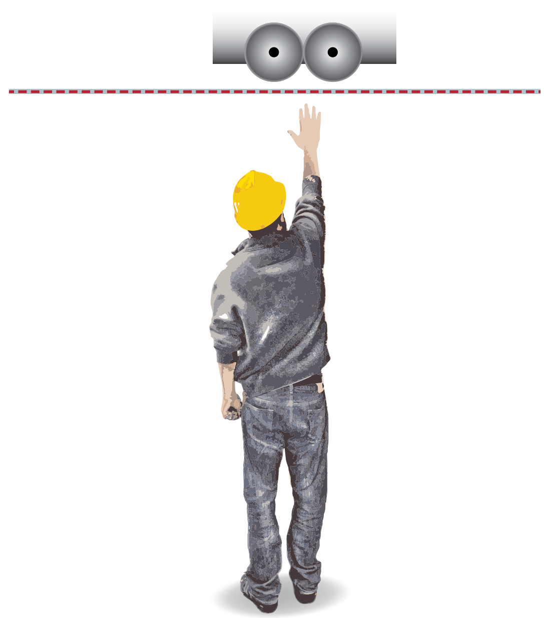


Figure 11.2.

Guarded by location means that a hazard is beyond the reach of a worker when working under or around elevated conveyors.

2

Guards – General. Here it notes that 'guarded by location or position' describes locations that are automatically protected because of their distance from the floor, platform, walkway, or working area.

In 2.13.2.2 the standard notes that all accessible shear and nip points which create a hazard shall be safeguarded. As an explanation, it specifies that any nip or shear point is considered **accessible** if it is located less than 2.7 meters [≈9 ft] above any floor, platform, goods, or materials. [Boldface added for emphasis – Ed.]

For bulk-materials-handling applications, *AS/NZS 4024.3610* refers to *AS/NZS 4024.3611* which details the locations to be guarded **unless** they are guarded by location. [Boldface added for emphasis – Ed.]

Brazil

In Brazil, the minimum distance to be exempted from guarding requirements is established in *NR-12* (Section 12.85.1) as 2.70 meters [≈9 ft] "provided there is no circulation nor permanency of persons in [the] hazardous areas."

Canada

Canadian Standards Association (CSA) *Standard Z432 (R2014) Safeguarding of machinery* specifies in Annex C.1:

> If there is a low risk from the danger zone, then the height of the danger zone shall be 2500 mm [≈99 in.] or more.
> If there is a high risk from the danger zone, then
>
> (a) either the height of the danger zone shall be 2700 mm [≈9 ft] or more; or
>
> (b) other safety measures shall be used.

[The Annex is not a mandatory part of the standard, 'but is written in mandatory language to accommodate its adoption by anyone wishing to do so.' – Ed.]

Without reference to 'Guarding by Location,' the recommendation in the IRSST publication *A User's Guide to Conveyor Safety: Protection from Danger Zones* is that a guard must be provided if a "hazard is less than 2.5 m [≈99 in.] from floor or working platform." The publication then offers the footnote: "Regulation Respecting Occupational Health and Safety [which covers Quebec] specifications are 2.1 m [≈7 ft] but international standards specify 2.5 m [≈ 99 in.]."

The Province of Alberta goes a step further, as the Work Safe Alberta publication, *Best Practices on Conveyor Safety*, specifies preventive measures must be implemented when a conveyor hazard is "2700 mm [≈9 ft] or less from the floor or working platform."

Europe

European standard *DIN EN 620 Continuous handling equipment and systems – Safety and EMC requirements for fixed belt conveyors for bulk materials* specifies in 5.1.6.2 that "when the clear height under moving parts is less than 2,5 m [≈99 in.], the moving parts shall be provided with fixed enclosing guards."

The standard continues: "Where walkways are provided under the conveyor for inspection, cleaning and maintenance purposes the clear height shall be at least 2,0 m [≈79 in.]."

These distances are reinforced in *BS EN ISO 13857:2008 Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs*. Here it specifies in section 4.2.1.2: "If there is a low risk from the hazard zone, then the height of the hazard zone shall be 2500 mm [≈ 8.25 ft] or more." Section 4.2.1.3 follows with "If there is a high risk (see 4.12) from the hazard zone, then the height of the hazard zone shall be 2700 [≈ 9 ft] or more."

South Africa

The 2016 edition of the *Safety Around Belt Conveyors* Guideline from the Conveyor Manufacturers Association of South Africa Limited offers the following:

> Any pulley or idler, which is 3,5 metres [≈11.5 ft] or more in height and there-

> fore beyond an upward reach, may be regarded as being positionally safe and need not be guarded.
>
> The possible reduction of this safe clearance by a build-up of spillage or discharge of material shall, however, be borne in mind.

United States

The Mine Safety and Health Administration (MSHA) regulations in 30 C.F.R. sections 56/57.14107 specifies that "guards shall not be required where the exposed moving parts are at least 7 feet [≈2.1 m] away from walking or working surfaces."

ASME B20.1-2015 Safety Standard for Conveyors and Related Equipment also notes in section 5.9.2 Guarding by Location or Position (c):

> When a conveyor passes over a walkway, roadway, or workstation, it is considered guarded by location if all moving parts are at least 2.44 m (8 ft.) above the floor or walking surface or are otherwise located so that personnel cannot inadvertently come in contact with hazardous moving parts.

ASME B20.1-2015 also notes in 5.10 Headroom (a):

> When conveyors are installed above exit passageways, aisles, or corridors, there shall be provided a minimum clearance of 2 m (6 ft. 8 in.) measured vertically from the floor or walking surface to the lowest part of the conveyor or guards.

In the marine terminal regulations presented in *29 CFR 1917.151(h)(1)*, OSHA notes:

> ... rotating parts, such as gears and pulleys, that are located seven feet (2.13 m) or less above working surfaces shall be guarded to prevent employee contact with moving parts.

In its regulations for Mechanical power-transmission apparatus *29 CFR 1910.219* (d)(1), the OSHA requirements state:

> ... pulleys, any parts of which are seven (7) feet [≈2.1 m] or less from the floor or working platform, shall be guarded in accordance with the standards specified in paragraphs (m) and (o) of this section.

[Paragraphs (m) and (o) present the general requirements for standard guards; i.e., (m)(1)(i) "... expanded metal, perforated or solid sheet metal, wire mesh on a frame of angle iron, or iron pipe securely fastened to floor or to frame of machine," and (m)(ii) "… free from burrs and sharp edges."– Ed.]

The Problems with 'Guarded by Location'

The obvious problem for designers is: Which standard applies? Equipment often is manufactured in one country to be supplied and installed in a second country, and then resold as used equipment to a third country. The variation from 2.1 to 3.5 meters [≈7.0 to 11.5 ft] is too much to allow for any global compliance. Simply meeting the minimum standard may mean a specification does not eliminate a hazard. For those designers who are liability-conscious, the 3.5 meters [≈11.5 ft] safety distance is the obvious choice, but this choice may introduce costs that the owner who buys on low bid will not pay. This issue points to the need for global standards for conveyor safety.

The issues that allow or even encourage at-risk behaviors around conveyors—usually in order to maintain production or prevent equipment damage—are generally not negated by location or position.

Most regulations do not account for the potential buildup of spillage or accumulation of carryback, which can easily change the distance between the working surface and a hazard. (**Figure 11.3.**) It is common practice in many maintenance situations to purposely build a pile of material or fill a bin to gain access for service or inspection. Using tools to extend a worker's reach to clean return rolls while the belt is running is a common, yet hazardous, activity contributing to serious and possibly fatal accidents. Drive belts or chains may have been guarded by location when functioning but become unguarded by location when broken and flung around by a still rotating drive or driven component. Often a conveyor will be 'jogged' or even run at full speed for inspections and checking repairs or adjustments.

Maintenance activities may involve man-lifts or ladders that place a worker in close proximity to a hazard that is supposedly guarded by location. In this case, the safe distance rule does not adequately protect the worker(s) from accidental contact. Components normally considered guarded by location present hazards to maintenance workers because they may not be locked out when the conveyor drive undergoing service is locked out.

The 'guarding by location' exemption does not address these dangers. Consequently, it must be seen that these 'guarding by location' rules are ineffective as a safety measure, especially where belt conveyors are concerned.

BEST PRACTICES

Despite its acceptance in various regulations, the practice of calling moving components on conveyors 'guarded' solely because their installation is at least a specific distance from the worker(s) is outdated as a concept and ineffective in application. It should be discontinued.

- Guard all nip points, shear points, and moving or rotating components, regardless of location or access.

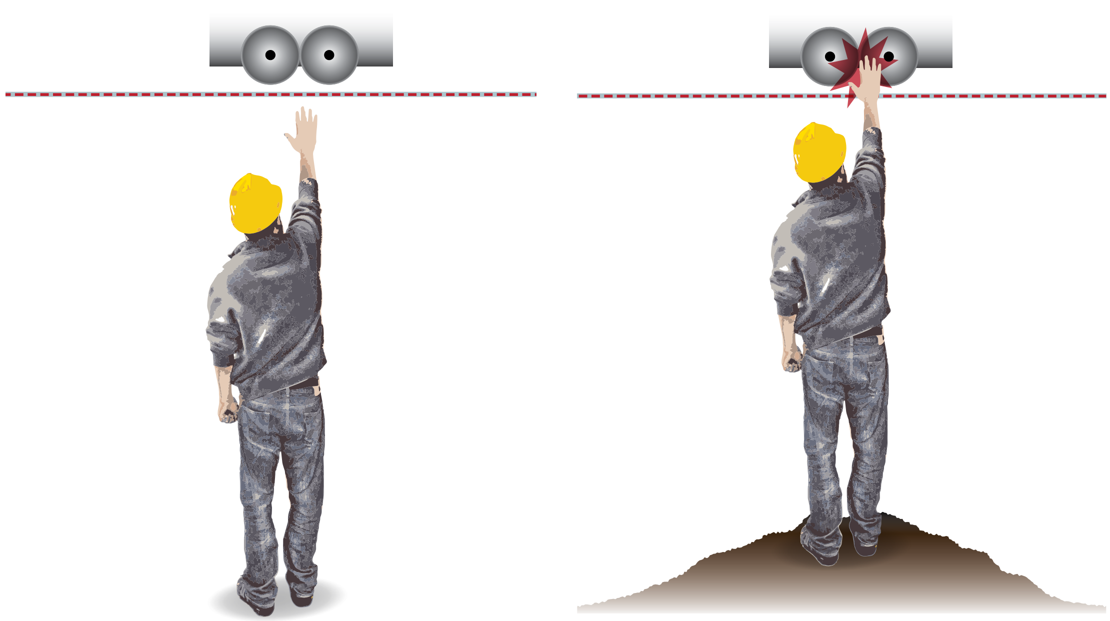
CLOSING THOUGHTS
Put an End to the Myth

Despite its nearly global acceptance as a concept in industrial safety, the practice of 'guarding by location' remains a problem for applications on overhead conveyors. At best, the concept provides a vague standard that is subject to changing interpretations and circumstances; at worst, it perpetuates hazardous conditions that endanger workers.

It is time to accept—as far as conveyors are concerned—that 'guarded by location' is a myth. As such, it is a concept that should be abandoned in order to make conveyors—and those who work on and around conveyors—safer. ⚠

Figure 11.3.

In plants where bulk materials are handled, an accumulation of fugitive materials (as shown at right) can bring workers closer to hazards that were once considered guarded by location by reducing the distance to the potential danger, thus creating an unguarded hazard.



2

Chapter 12 Return-Roller Guards

Figure 12.1.

Return roller guards are commonly installed on belt conveyors to reduce the risk of injury.

INTRODUCTION

One of the types of protection commonly required on belt conveyors are guards placed at or near the return idlers. (**Figure 12.1.**)

Unguarded return rollers that can be contacted by workers are particularly hazardous, because they create in-running nip points across the entire width of the belt into which personnel can be drawn and trapped. Because return rollers are often exposed to contact when workers pass under the conveyor or clean around it, guards are typically needed on return rollers. Return rollers are also dangerous because they represent a falling component hazard if their mounting breaks. Installed under the returning belt, they are not easily seen—workers must often be on their knees—so they remain uninspected.

Another reason return idlers should be guarded is that they are in contact with the dirty side of the belt. As such, they are particularly subject to the accumulation of fugitive material. The material can appear both on the roller itself, and on the ground (or other surfaces) below the idler as a result of the cleaning effect of the belt running over the idler. These material buildups are likely to draw the attention of workers who will perform cleanup chores on or around the conveyor. In the course of their cleaning responsibilities, these workers risk coming into contact with the in-running nip point. (**Figure 12.2.**)

[This section deals with single-roller (flat) return idlers; V-return idlers are sometimes seen on belt conveyors. Guarding V-return idlers requires a nip-point guard that matches the contours of the V-rollers; barrier guards can be applied universally. –Ed.]

In the authors' opinion, all in-running nip points are serious hazards that should be guarded with fixed side guards. A standard should be applied to prevent reaching any nip point through a combination of reaching-around-the-guard distance requirements and the prevention of workers crawling under or over an unguarded conveyor.

Guarding the Underside of the Conveyor

One solution is to completely hide the rollers on the bottom of the belt behind a continuous barrier (deck, ceiling, or panel guard). Guards like this are particularly effective where persons will pass under belt conveyors.

This guard can be solid, like a wall or decking; or contain openings, like a fence. (**Figure 12.3.**) If it has openings, care must be taken to make sure the appropriate opening sizes and distances are maintained to prevent hazardous contact. However, care must be taken so that the openings are large enough to allow fugitive material particles to fall out, so that the material does not accumulate to the point where it prevents the roll from turning. If the barrier is more solid, some method for the safe removal of fugitive material should be provided.

Caution must be taken against large lumps passing through and causing a falling material hazard. Openings in the guard should be large enough to allow stray material to fall through. However, the mesh should not be so large as to allow falling lumps to create an injury hazard.

Nip-Point Guards

Return-roller guards are usually intended as pinch-point guards that prevent worker contact with an in-running nip point. (**Figure 12.4.**) Nip-point entrapment is one of the main hazards leading to fatal accidents when maintaining or cleaning around belt conveyors.

The guard should be set close to the belt to isolate the in-running nip point between the

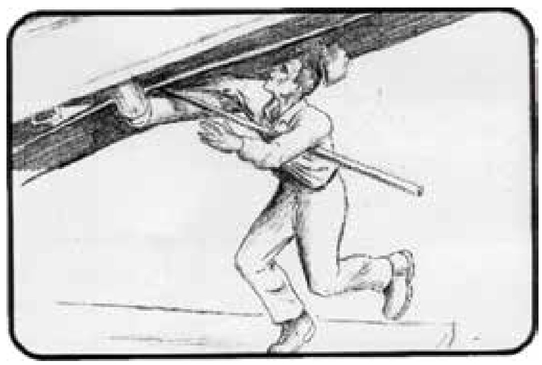


Figure 12.2.

When cleaning around unguarded return rollers on operating conveyors, workers can be injured by coming into contact with in-running nip points. Artwork courtesy of U.S. MSHA.

Figure 12.3.

A continuous barrier guard can be used to isolate an extended row of return rollers from workers.

Figure 12.4.

An in-running nip point with sufficient space to allow the entrapment of a worker's limb should be guarded.

2

roller and the belt. It should extend past the ends of the roller to further protect the nip points there. The ends of the roller are thus covered to further protect against accidental contact with the nip points.

The design and installation of the guard keep it close to the front (the in-running side) of the roller. This reduces the possibility of a worker's tool or body part becoming entangled in the roller.

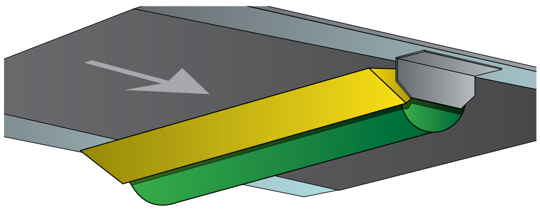


Figure 12.5.

A deflector guard is installed on the in-running side of the roller to prevent accidental contact and the risk of entrapment.

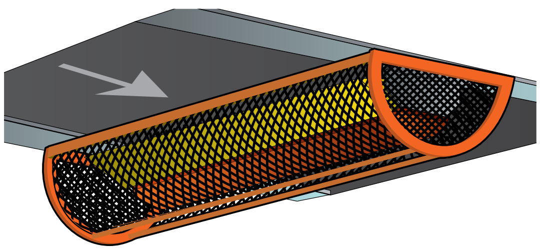


Figure 12.6.

Often constructed of mesh to allow inspection and reduce the accumulation of material, a cage guard goes around the entire roller.

Return-roller guards do not have to completely enclose the roller, although it should be designed to direct any worker's limb or tool away from the pinch point, rather than allowing it to be pulled into the nip.

There are two forms for this guard: a fence or barrier that acts as a deflector on the in-running side of the roller, (**Figure 12.5.**), or a basket or cage around the entire roller. (**Figure 12.6.**)

Deflector Guards

A common practice for guarding nip points on idlers is to use a plastic or metal curved plate attached to the idler bracket to create a deflector-style guard. (**Figure 12.7.**)

A deflector-style return-roll nip-point guard basically consists of an obstruction running

Injury from Unguarded Return Roller Draws $60,000 MSHA Fine for U.S. Quarry

In the United States, an injury resulting from the failure to have a proper guard on a return roller cost a quarry a $60,000 fine from the Mine Safety and Health Administration (MSHA).

Mainline Rock and Ballast, Inc.'s Torrance Quarry in New Mexico was assessed the fine after a 2009 accident in which a worker suffered near fatal injuries when he was pulled between the belt and a roller. The worker had been kneeling to clean under the conveyor which was positioned 33 inches [≈838 mm] above the ground. He was injured when a return roller 'grabbed' the shovel and drew him into the unguarded roller.

The worker spent two-and-a-half months in the hospital recovering from severe internal injuries requiring a tracheotomy and surgery to his pelvis, pancreas, hip, and spleen. He suffered permanent damage to his kidneys and also broke his arm, his collarbone, and all of his ribs.

The fine was levied by MSHA for violation of *30 CFR section 56.14107(a)*, the mandatory safety standard requiring that moving machine parts be guarded to protect miners from contacting them.

The fine was assessed by MSHA despite the quarry's contention that the roller was guarded by location, and that there was no access without intentionally going underneath the conveyor. The company further argued in an appeal the standard does not cover an intentional action, arguing that this was not accidental contact, as the worker went under the conveyor to dislodge rocks and then clean with his shovel as part of his regular duties.

The findings and fine were affirmed by an Administrative Law Judge, and when appealed, both were upheld in a 2012 ruling by the U.S. Court of Appeals for the 10th Circuit. (See Mainline Rock & Ballast, Inc. v. Secretary of Labor, 693 F.3d 1181, 10th Circuit 2012.)

In summary, the failure to recognize and guard the hazard created by an accessible return roller resulted in costly consequences for the worker and for his employer.

The key then for the worker is to add safety to the mix. This makes our mantra: **Production Done Safely™**.

the width of the roller. This device serves as a deflector to prevent entry to the nip point, or as a ramp to steer any tool or limb over the roller and thus prevent it from being pulled in. (**Figure 12.8.**) This guard is mounted in close proximity to both the belt and roller preventing anything reaching past the deflectors.

Consideration must be given to regular cleaning of this deflector to prevent accumulation of material on its inclined surfaces.

Curved plastic return-roll guards are not effective in stopping a worker from being drawn into the nip point; it can be foreseen that curved metal-plate roll guards could bend as well, allowing a person to be drawn in. It is the authors' opinion that curved plastic or sheet metal nip-point guards are not sufficient to prevent being drawn into a nip point because they can bend. This can expose workers to new hazards that can occur if the belt lifts off the roll. The authors do not recommend in-running guards of the type shown in **Figures 12.5**, **12.7**, and **12.8**, because the (often-required) 5 millimeter [≈0.2 in.] clearance is impractical in bulk-materials handling due to buildup on rollers. In addition, these guards are often too flimsy to prevent entrapment.

Side Plate Guards

There are circumstances where the guard does not need to extend the full length of the roller. These applications are where the conveyor's proximity to the ground or to other guards or obstructions would prevent a worker from reaching in past the roll end to contact a hazard under the middle of the belt. In these cases, a side plate on the outside of the roller can be used to prevent access to the hazard zone.

Side plates can be combined with cage-style guards when the combined hazards of falling components—for example, hazard guarded by location but over a walkway or building—and nip-point access—for example from the walkway—are present. (**Figure 12.9.**)

A User's Guide to Conveyor Belt Safety: Protection from Danger Zones, published in 2009 by Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) in Quebec, allows these deterrent devices as return-roller guards on belts no higher than 700 millimeters [≈27.5 in.] above the floor. As this publication notes, even when the belt is on a level (non-inclined) run and close to the floor, the roll end guard should extend at least 300 millimeters [≈12 in.] below the bottom of the roller to further reduce the potential for workers to reach under the guard. (**Figure 12.10.**)

Figure 12.7.

This deflector guard serves as an obstruction that runs the width of the belt to prevent worker access with the roller. Photo courtesy of United States Mine Rescue Association.

Figure 12.8.

A deflector guard acts as a ramp to steer any tool or limb on the belt over the in-running pinch point.

Photo courtesy of United States Mine Rescue Association.

Figure 12.9.

This 'homemade' guard offers in-running and end protection; the exposed wire ends may violate the concept that a guard should not be a hazard in itself. Photo courtesy of United States Mine Rescue Association.

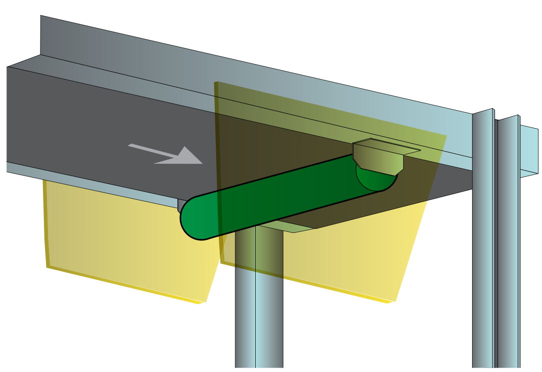


Figure 12.10.

Side plates on roller guards can improve safety if there is limited clearance directly below the roller.

The publication additionally notes that when these side plates are installed, housekeeping —that is, cleaning around the conveyor— "must only be performed while the conveyor is not operating."

Martin Engineering recommends cleaning only be performed when the conveyor is shut down, unless the elevation of the conveyor and the installed guarding allow for safe cleaning under the conveyor. Cleaning of rollers should only be done when the system is locked out, tagged out, blocked out, and tested out. (**See Chapter 24 Working Safely Around Conveyors.**)

Cage-Style Guards

Another approach for return rollers is to guard the entire roll using a fixed guard with side plates. (**Figure 12.11.**) These guards are usually in the form of a cage featuring a screen or slotted mesh to allow inspection, and for material to fall out or be cleaned out. This mesh must be selected so it aligns with the specifications for pinch-point protection. The size of the mesh needs to be small enough to prevent contact by reaching through. (**See Chapter 10 Guarding.**)

2

Figure 12.11.

A guard that encloses the entire roller and has side plates can reduce the risk of injury to workers.

Figure 12.12.

Basket guards can collect fugitive material inside, and will require cleaning.

Figure 12.13.

Return-roller guards can be designed with panels that open to allow the removal of accumulated material.

Due to the accumulation of material inside (**Figure 12.12.**), these guards pose operational problems and are often left open in the field, thus negating the reason they were installed.

If the mesh openings in the guard are small, material may accumulate inside the guard. Therefore, guards should be designed so routine clearing of spillage and collected material can take place without disturbing the guard or the installation. This cleaning can be done manually (for example, with a scraper) and/or with a water spray. Manual cleaning should be undertaken only when the conveyor is locked out; it might be possible to clean the guard from a safe distance while the belt is running, using a powerful water spray (for example, a fire hose) although that procedure merely moves the problem. The material falls somewhere and creates a mess at that location.

It is important the guard allows easy removal for idler inspection, lubrication, or roll replacement when the conveyor is properly shut down and locked out. The guard should be designed to allow cleaning the roller or bearing lubrication without having to remove the entire guard; often this involves removable sections or swing-down panels. (**Figure 12.13.**)

Catcher Baskets

Another risk of injury originating from return idlers would occur if a roller were to break loose from its mounting and fall. Sometimes these loose rollers can be caught in the conveyor structure (**Figure 12.14.**); other times the roller can fall to the ground or other surfaces below the conveyor. (**Figure 12.15.**) If the fall is far enough—or the roller was installed over public areas, roadways, or plant structures—this failure risks injury to personnel and damage to vehicles, structures, and other property. (**Figure 12.16.**)

If a standard idler mounted 60 meters [≈200 ft] above the ground were to break loose and fall, that 20 kilograms [≈44 lb] roller would strike the ground at 31 meters per second [≈69 mph]. That equates to the same energy as being struck by a car traveling 7 meters per second[≈15 mph]. While that may not seem like much, know that if a person is struck by a car, the entire force is spread over the contact area of the victim. While this may not kill, however, a person would definitely be thrown a considerable distance and probably suffer serious injury. If a worker is struck by a falling idler, the entire impact force is concentrated in a small area. Such pressure could cause broken skin, bones, crushed internal organs, and perhaps even instant death, depending on where the idler strikes.

Consequently, these conveyors need the installation of another form of return-roller guard, referred to as a basket guard. (**Figure 12.17.**) The basket guard is needed on only those applications where the position of the roller is overhead far enough so that its fall could cause injury or damage.

However, it must be emphasized that this basket is not a guard against pinch-point hazards. The basket is intended to catch a roller that breaks loose from its mounting. The basket must be installed closely enough to the roller so that a falling roller will not achieve sufficient fall force to damage the basket and/or bounce out to escape. (**Figure 12.18.**)

Many of the design considerations for catcher baskets are the same as with the roller pinch-point guards; however, the return basket does not need to be installed so close to the belt to eliminate pinch-point hazards.

The idler should be located high enough to eliminate the risk of accidental or incidental contact, as these baskets do not guard against in-running nip-point hazards.

Figure 12.14.

Overhead rollers that come loose might be caught in the conveyor structure.

Photo courtesy of United States Mine Rescue Association

Figure 12.15.

Rollers that come loose from their mounting can fall to the ground, risking injury to workers or damage to equipment.

Photo courtesy of United States Mine Rescue Association.

Figure 12.16.

A conveyor that crosses a road or walkway poses the risk of injury if a roller were to fall from its mounting.

Photo courtesy of United States Mine Rescue Association.

Figure 12.17.

Installed below an overhead roller, a basket will catch the roller if it becomes dislodged.

Figure 12.18.

Catcher baskets are installed to reduce the risks of injury or damage if a roller were to come loose from its overhead mounting.

It is possible for an oversized catcher panel to be installed overhead so that it covers several rollers. This panel could be raised and lowered with a winch to provide easier access for cleaning and idler service.

While usually not specifically referred to, this type of guard would be included in the regulations concerning the prevention of flying or falling material. As an example, European Standard *EN 620* section 5.1.5.1 Parts of Machinery includes the following: "Return idlers above working or traffic areas shall be fitted with a retaining device (e.g. catching trough) to prevent items falling." (**See Chapter 14 Protection from Falling Material.**)

Return rollers in elevated positions can be guarded effectively with a catch basket with large openings; this should catch falling idler rolls while accumulating only limited amounts of fugitive material and allowing easy cleaning.

Mounting of Roller Guards

Obviously, the conveyor will need to be shut down and locked out to allow installation and service of return-roll guards. Installation should follow manufacturer directions to achieve proper clearances and installation.

To eliminate the risk of entering the pinch point, return-roller guards should be installed as close as possible to the belt and idler without actually touching. *EN 620* section 5.1.4.2 specifies a maximum clearance of 5 millimeters [≈3/16 in.] between the guard and surface of the belt or roller. The Australian/New Zealand conveyor standard *AS/NZS4024.3610* requires in section 2.13.5.4 Nip point guards, that the gap between moving and stationary parts be no more than 5 millimeters [≈3/16 in.]. (**Figure 12.19.**)

The installation of a guard this close to the nip point poses some practical problems. Many pulleys and some idlers have out-of-roundness tolerances greater than 5 millimeters [≈3/16 in.]. In addition, this specified clearance is nearly impossible to maintain when there is material buildup on the roller or pulley.

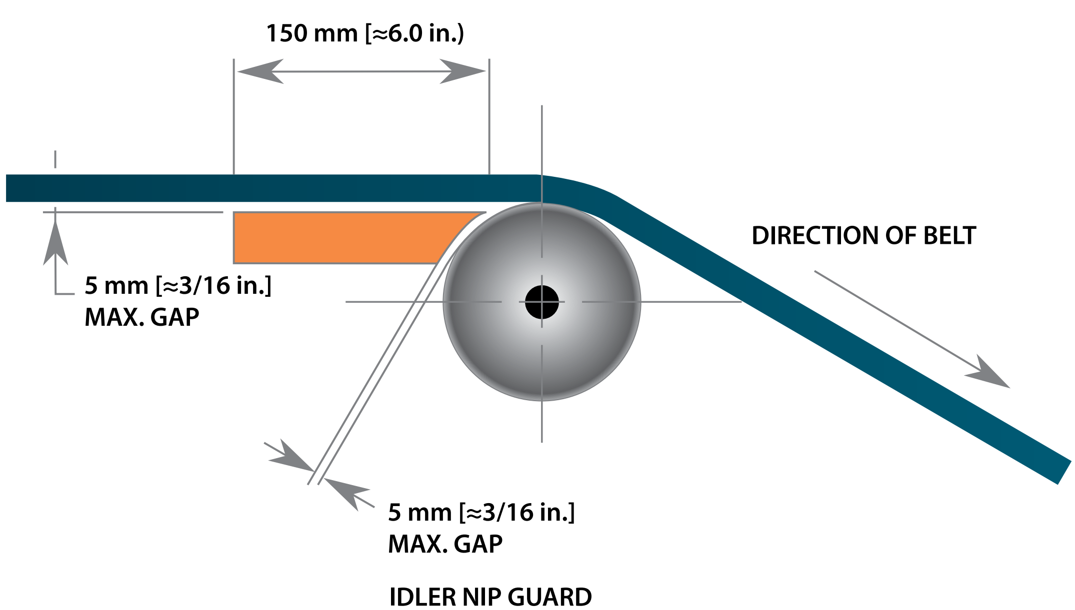
Individual return-roll guards often are installed on the 'hanger' bracket used on the typical return idler. The guards are typically supplied with a universal mount to suit an idler from any supplier, although the size of the roller or bracket may need to be specified.

Otherwise, the guard can be bolted to the conveyor's stringers. The guard manufacturer should design the equipment to allow installation either on the bottom or outside of the steel stringers and provide some adjustability in case of different structural standards.

2

Figure 12.19.

Maximum clearances for nip-point guards are specified in several standards from around the world.



REGULATIONS AND STANDARDS

The nip-point hazard may seem more severe for pulleys than idlers and return idlers in particular. Some standards actually state that if the belt is low tension and can be lifted 50 millimeters [≈2 in.] off the roller, the nip-point hazards does not need to be guarded. While not an acceptable practice, the reasoning behind this is if the belt can be raised, a worker will be able to escape if caught.

The authors do not recommend this exception because many injuries have occurred where the skin is removed to the bone before the hand can be removed from the post .

If personnel will work under an accessible conveyor while it is operating, or if they can travel under it, the full width of in-running nip points formed by the return idlers needs to be guarded.

Nip points on pulleys are commonly guarded either by chute walls at the discharge or by a fixed guard around the tail pulley. Quite often bend pulleys and idlers in convex curves are not guarded, but should be.

Generally, regulations are not specific to return-roll guards. Typically, the applicable regulations are provided in the general, conveyor, or machine guarding standards, or in the requirements for the prevention of falling or flying material.

The key here is the accessibility of the conveyor and its components. If the worker cannot reach the pinch points—such as return rollers—those pinch points are considered 'guarded by location.' The definition of guarded by location varies by jurisdiction.

The authors do not agree with the practice of guarded by location. (**See Chapter 11 The Myth of 'Guarded by Location.'**)

In the United States, the Occupational Health and Safety Administration (OSHA) relies on the American National Standards Institute standard *ANSI B20.1.1957,* as incorporated by reference in *29 CFR 1926.555(a)(8).*

The *ANSI B20.1* standard has been updated several times; the current version is the American Society of Mechanical Engineers' standard *ASME B20.1-2015*. This 2015 version specifies in section 5.9.2 Guarding by Location or Position subsection (c):

> When a conveyor passes over a walkway, roadway, or workstation, it is considered guarded by location if all moving parts are at least 2.44 m (8 ft) above the floor or walking surface or other located so that personnel cannot inadvertently come in contact with hazardous moving parts.

In *30 CFR 56/57 14107*, the United States Mine Safety and Health Administration (MSHA) specifies, "Guards shall not be required where the exposed moving parts are at least seven feet [≈2.1 m] away from walking or working surfaces."

For Australia, the *AS/NZS 4024.3610* standard specifies that shear and nip points "less than 2.7 m [≈108 in.] above any access floor, platform level, stored goods or materials shall be considered accessible" and therefore, should be guarded.

There are some justifiable concerns with the 'Guarded by Location' policy. (**See Chapter 11 The Myth of 'Guarded by Location.'**)

BEST PRACTICES
Guarding of Return Rolls

Both pinch-point guards and basket guards should be designed so that fugitive material will not accumulate to damage the roller, and that the enclosure provides a mechanism to allow cleaning and inspection of the roller.

Return rollers should not be considered guarded by location regardless of their position. That is because all return rollers will need inspection and maintenance; buildup below the rollers can change the guarded by location distance; and there remains the hazard from the falling of broken rollers.

Return Idler Pinch-Point Guard

All accessible return rollers are to be guarded with adequately constructed, installed, and maintained guards to prevent contact with in-running nip-point hazards.

Construction of these guards should comply with local standards, and/or with Martin Engineering Global Best Practices Guarding Standards, whichever is more stringent.

Overhead Return-Idler Catcher Basket

To prevent injury and damage, conveyor return rollers installed above occupied spaces, work areas, walkways, and roadways should be fitted with a basket-style guard which will capture and hold the roller in the event of it coming loose from its mounting.

CLOSING THOUGHTS
Many Happy Returns

With the proper guarding on return rollers, it is possible for personnel to work safely around the conveyor return. The guards should prevent contact with in-running nip points, and if the rollers are mounted overhead, the guards should eliminate the risk of injury from falling rollers.

It would be best if the 'Guarded by Location' designation was avoided and all return rollers were appropriately guarded. (**See Chapter 11 The Myth of 'Guarded by Location.'**) ⚠

2

Chapter 13 Takeups

INTRODUCTION
Taking Up with Takeups

All properly designed belt conveyors require the use of some form of takeup device. (**Figure 13.1.**) Takeup systems are used to adjust belt tension, to avoid belt slippage, reduce belt sag, compensate for belt elongation, and allow slack for belt installation and splicing.

As defined in the *Conveyor Terms and Definition (ANSI/CEMA 102-2006)* glossary produced by the American National Standards Institute (ANSI) and the Conveyor Equipment Manufacturers Association (CEMA), a takeup is:

> The assembly of the necessary structural and mechanical parts which provides the means to adjust the length of belts, cables, chains, etc., to compensate for stretch, shrinkage, or wear and to maintain proper tension.

In a 2009 article, “How to Design Take-up Travel for a Fabric Conveyor Belt” presented in the *Belt Line* newsletter of the National

Industrial Belting Association (NIBA), Mitesh Kadakia notes:

> The purpose of take-up devices in belt conveyors is to establish and maintain a predetermined level of tension in the belt. Maintaining correct take-up tension will lessen the chance of drive slippage and/or excessive belt sag.

Kadakia further explains:

> Drive slippage can result in excessive pulley cover wear, take-up counter-weight bounce, and possible belt breakage if the take-up counterweight bounces high enough. Excessive belt sag occurs when the belt tension is low and the belt droops (sags) between the idlers more than normal. ... Too little sag will create tracking problems due to the lack of frictional contact between the belt and the idler cans. Too much sag creates excessive friction between the belt and the idler cans, which, in turn, creates a higher horsepower requirement for the drive motor and accelerated wear of the pulley covers.

Functions of the Takeup System

Indian standard *IS 11592 : 2000 Selection and Design of Belt Conveyors – Code of Practice* lists four principal functions for a takeup system:

a) ensuring adequate tension of the belt leaving the drive pulley so as to avoid any slipping of the belt;

b) permanently ensuring adequate belt tension at the loading point and at any other point of the conveyor to keep the troughed belt in shape and limit belt sag between carrying idlers;

c) compensating for operating belt length variation due to physical factors (instantaneous tensions, permanent elongation, outside temperature, temperature of conveyed material, dampness, etc); and

d) making available, if needed, an adequate extra length of belt to enable rejoining without having to add an extra piece of belt.

In order to maintain optimal belt tension, it is important to allow adequate takeup travel length in the conveyor system design. Insufficient takeup distance will cause the takeup to reach its distance limit as it applies tension to the belt.

The takeup mechanism should be designed to provide sufficient travel distance to cope with the stretch of the belt. There are two forms of elongation; the first is permanent elongation, typically experienced in the first 30 to 60 days of use as the belt is loaded and tensioned. The second form is elastic elongation, which is a condition of expansion and contraction, similar to stretching and releasing a common rubber band. This occurs when the conveyor is started or the belt is subjected to varying loading conditions.

The type of takeup system and its location on the conveyor typically depends on the configuration and length of the conveyor and the available space.

No matter what type of takeup is used, it is critical to keep the takeup pulleys and associated bend pulleys, carriages, and tracks free of

Figure 13.1.

Takeup mechanisms remove slack from the belt, tightening the belt to apply tension for an efficient transfer of energy to move the belt and cargo.

Photo courtesy of United States Mine Rescue Association.

fugitive material, so the system can respond properly to changes in belt tension and stretch.

Types of Takeups

There are three common types of takeups. These are usually referred to by the mechanism that allows each to move and so accommodate the lengthening or shortening of the belt.

Figure 13.2.

On a screw takeup, the takeup pulley is moved by adjusting screws on either side of the pulley.

The types are: Manual, which is has a screw on each side of the pulley for adjustment; Automatic, which usually features a horizontal or vertical gravity mechanism; and Powered, which most often uses a winch or an air or hydraulic cylinder as the adjustment method.

Manual Takeups

This takeup typically uses threaded adjustments on either side of the pulley and so is usually called a screw takeup.

In a screw takeup system, the takeup pulley rotates in two bearing blocks which slide on stationary guideways. (**Figure 13.2.**) The pulley can move in or out, applying less or more tension on the belt. The pulley slides along a track; the sliding surfaces are suitably protected against ingress of dirt. In this system, the position is manually adjusted by means of

Take Up, Takeup, Or Take-Up?

Is it take up, takeup, or take-up? All of these usages are compound words, and all mean the same component system on the conveyor. Opinions vary on correct usage.

The 'closed' compound word 'takeup' and the 'hyphenated' compound word 'take-up' are more prevalent than the 'open' compound word 'take up.'

The publication *Conveyor Terms and Definitions ANSI/CEMA 102-2006* uses the hyphenated version: 'take-up.'

The American Society of Mechanical Engineers (ASME) *B20.1-2015 Safety Standard for Conveyors and Related Equipment* uses 'take-up' and the hyphenated version is also the spelling found in European standard *DIN EN 620 Continuous handling equipment and systems – Safety and EMC requirements for fixed belt conveyors for bulk materials,* and in the Australian standards *AS/NZS 4024.3610 Safety of Machinery – Conveyors – General requirements* and *AS/NZS 4024.3611 Safety of Machinery – Conveyors – Belt conveyors for bulk materials handling.*

Dictionaries—both printed and online—commonly suggest the hyphenated version. The glossary in Martin Engineering's book, *FOUNDATIONS™, The Practical Resource for Cleaner, Safer, More Productive Dust & Material Control, 4th Edition,* also uses the hyphenated version.

A Guide to Conveyor Safety published by South Australia's Mining and Quarrying Occupational Health & Safety Committee uses 'takeup,' as does CEMA's *Belt Conveyors for Bulk Materials.*

One explanation is when a compound word is used as a noun, it is not hyphenated. When the compound word is used as an adjective followed by a noun, the word is usually hyphenated.

The website *englishplus.com* explains "as some words are more widely used, the hyphen is dropped. For example, in the early 1800s the word blackbird was usually spelled black-bird. Now the hyphen has been dropped."

For the sake of consistency, this publication will use the closed compound word, 'takeup,' except when presenting a direct quotation that uses another spelling. In passages that are quotes from attributed sources, the original spelling will be maintained.

two screws—one on each side of the pulley—which can be tightened simultaneously or successively. The screws should be tightened identically to keep the pulley in alignment with all three axes of the desired belt path.

At a minimum, the adjustment range should be sufficient to allow for belt splicing and belt stretch. The longer the conveyor, the longer the adjusting screws need to be. For these reasons, a screw takeup is typically used only with a short conveyor such as a feeder belt or an in-plant conveyor with lower tension requirements. These conveyors are typically less than 60 meters [≈200 ft] in length.

In this system, the applied tension is usually not measurable and requires adjustment to compensate for belt stretch. This can lead to significant over- or under-tensioning of the belt.

The main problem with the use of a screw takeup is that it requires a vigilant and careful operator to observe when adjustment is required. Correct tension adjustment with this system can be very difficult.

Manual takeups are sometimes used to adjust the tracking of the belt, as they present an easy way to alter the angle of a tail pulley relative to the conveyor structure. This practice is not recommended, as it can change the belt tension in amounts that are uneven on one side to the other, resulting in additional tracking problems and the risk of belt or bearing damage. In addition, these adjustments are often made while the belt is running, with resulting risk to the worker(s). Therefore, the manual takeup's adjustment mechanism must be designed so the adjustment mechanism is outside of the guard.

Automatic Takeups

Automatic takeups are designed so they will automatically maintain the minimum tension required to drive the belt and compensate for belt stretch, and they also aid in storing sufficient belt length to allow for splicing. They usually use the force of gravity—as represented by a counterweight—to move the takeup pulley and so keep the belt tight. (**Figure 13.3.**)

Most belt conveyors of any significant length use either horizontal or vertical gravity automatic takeup systems

A gravity takeup can be mounted anywhere in the system and is often located in a place on the conveyor to minimize the required belt strength or to minimize dynamic effects during conveyor start-up and shutdown.

In a gravity takeup, the belt is tensioned by the pull of gravity on a weight assembly. (**Figure 13.4.**) The assembly is usually held vertically in a structural tower that allows for the weight and pulley to travel up and down in a guided frame as tension in the belt changes and as the belt stretches and contracts. Sometimes the takeup weight tower is mounted to the side of the conveyor, and the force is applied to the takeup pulley via a system of wire ropes.

The common arrangement for a gravity takeup calls for the returning belt to run around a

Figure 13.3.

In a gravity takeup, the pull of a weighted assembly (counterweight) tightens the belt.

Photo courtesy of United States Mine Rescue Association.

Figure 13.4.

If the gravity takeup assembly becomes misaligned, it can cause the belt to run off-center.

2

bend pulley and then down at an angle to a suspended takeup pulley. After wrapping around the takeup pulley, the belt is directed back up to another bend pulley, which redirects the belt along its original path toward the tail pulley. The pulley is suspended from the belt in a frame and pulled downward by the weight, creating the force to keep the belt suitably tight. This is a vertical gravity takeup.

There are also horizontal gravity takeups. Here, the motion of the pulley is horizontal, as relayed to the carriage-mounted pulley through gravity on a weight connected to the pulley with wire ropes and sheave mechanism.

Automatic takeups offer a number of benefits:

2

- They are self-adjusting and automatic, and so, better cope with belt stretch and the stress of start-up.
- They allow for greater takeup movement than manual takeups.
- They are suitable for horizontal or vertical installation.
- They can be used on any length conveyors.
- They store extra length of belt for splicing and can be designed for systems where there is a need to frequently extend the belt length.

It is critical to keep the gravity takeup mechanism in proper alignment and level, as any off-center movement or position can produce a misalignment of the belt.

Powered Takeups

A powered takeup uses force supplied by a power source to move the pulley, thus stretching the belt. (**Figure 13.5.**)

Hydraulic, pneumatic, or electrically powered takeup devices have often been used in circumstances where the available space limits the ability to install a gravity takeup system. In applications where space is limited, such as underground mines or on movable conveyors, powered takeups are common regardless of conveyor length.

In a powered system, the takeup pulley is mounted on slides or on a carriage allowing it to move freely. Travel is generally horizontal within the conveyor frame, while a constant tension and adjustment for belt length is automatically maintained by a winch or cylinder. Typically an arrangement of steel ropes con-

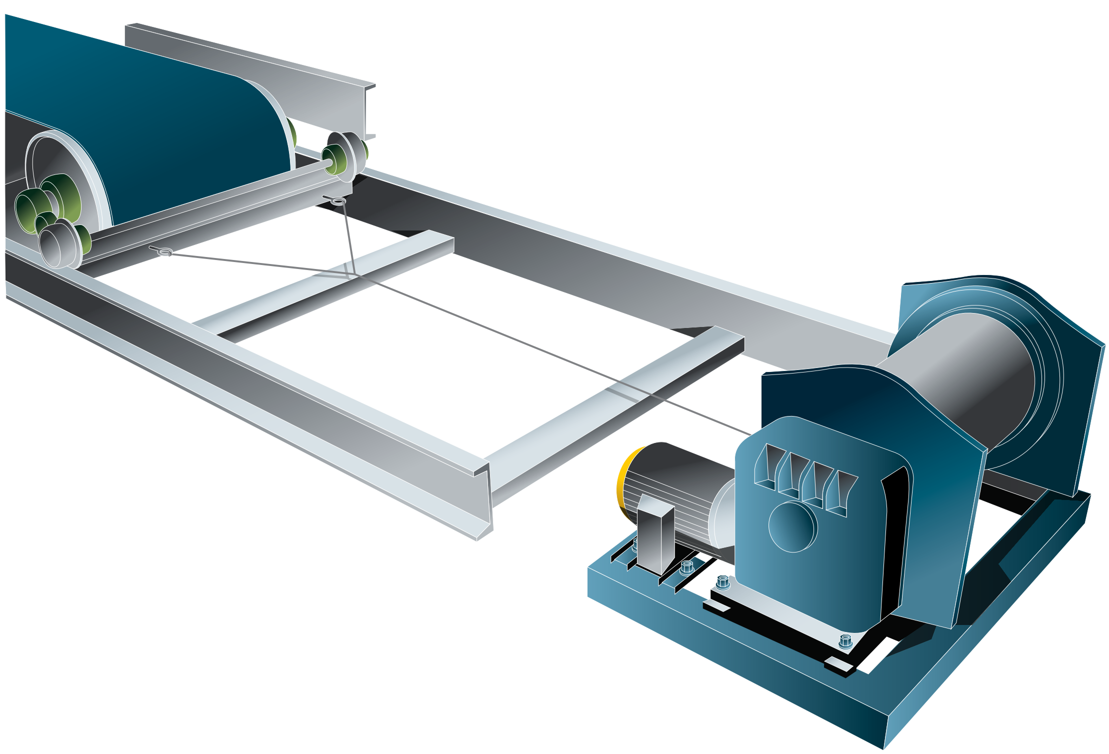


Figure 13.5.

A winch takeup uses a motorized winch and cable to change the pulley location to adjust belt tension.

nects the takeup carriage to the power source, while the slides or rails and the design of the carriage keep the takeup pulley square to the belt's travel. In some cases multiple wire-rope pulleys or bend pulleys can be used to make the system more compact. For longer belts, it is common to use a powered takeup with a controller to control the speed of movement to assist in keeping the belt tension within safe limits.

These systems also require careful checking of belt tension and may lead to the belt being over-tensioned.

A tension indicator may be included between the winch or cylinder and the pulley. Winch takeup devices can also be used in an automatic arrangement when tension regulation can be applied by employing load cells or electronic sensors. Output from these sensors activates the winch motor to run for a specific number of turns or to achieve a predetermined belt-tension value.

Hazards of the Takeup and How to Control Them

The inclusion of the moving parts in takeup pulley mechanisms, such as suspended weights and pulley carriages, in a conveyor design creates moving parts and nip points. These will need to be guarded as will other nip points on the conveyors. (**See Chapter 2 Danger Zones of Belt Conveyors; see Chapter 10 Guarding.**)

But in addition, there are other hazards, including the potential for the fall of counterweights and the dangers caused by mistracking belts.

The Fall of the Counterweight

If a belt breaks, a gravity takeup pulley and its suspended counterweight will fall. Since the takeup weight is often substantial—often thousands of pounds are required to stretch a cargo-laden belt—the falling weight can cause significant structural damage and—if workers are nearby—serious or fatal injuries. (**Figure 13.6.**)

The 7th edition of CEMA's *Belt Conveyors for Bulk Materials* notes:

> Should the belt or tension cable fail, these weights are released to free fall onto the tower bottom and supporting structure. These potential and kinetic energies can be very high and can cause extensive damage to foundations and steel structures, and injury to nearby personnel. Often these towers are overhead of walkways or sensitive plant infrastructure.

The common practice of placing a pile of bulk material or used equipment tires under the takeup weight generally does not mitigate damage to the takeup system or structure and often adds to the damage from secondary reactions. Such systems rarely absorb the impact uniformly, resulting in damage to the structure or takeup from large, uneven forces. An additional point as to why old tires, springs, or piles of dirt are not effective is that the energy absorption efficiency of these 'homemade' systems is typically three to four times less than the engineered shock absorber or strain energy-based takeup safety devices.

Devices are available for safely controlling the fall of takeup weights. Safety devices that absorb the kinetic energy are useful to control the maximum structural loads on the tower base and supporting structure. These devices are available for single impact or for multiple impacts. The application and frequency of belt failure determines the type of energy absorption required.

Figure 13.6.

A free-swinging or unconfined counterweight may damage property and injure workers.

Photo courtesy of United States Mine Rescue Association.

2

A related hazard comes from the failure of the wire ropes used in a gravity takeup or in a powered or winch system. (**Figure 13.7.**) The wire rope, connections, and the sheaves are subject to wear as they are being worked in an atmosphere that usually involves abrasive and/or corrosive bulk materials. When a wire rope breaks under tension, it can create a whipping hazard which can lead to serious injury or death. When wire-rope systems are used, it is important to guard not only the takeup mechanism but the rope's travel path as well.

Hazards from Mistracking

The most common hazard created by improper takeup operation is belt mistracking. This mistracking can result from several causes, including loose takeup guides, accumulations of fugitive material on the takeup's bend and takeup pulleys, failing pulley bearings, or an off-center or off-level condition of the takeup pulley. These conditions allow the takeup mechanism to apply unequal force on one side of the belt, with resulting belt wander. This unequal force can cause premature bearing failure.

Figure 13.7.

The wire ropes used in a gravity takeup can pose a workplace hazard.

Photo courtesy of United States Mine Rescue Association.

Figure 13.8.

The accumulation of fugitive material can adversely affect the operation of the takeup and also endanger the belt.

Photo courtesy of United States Mine Rescue Association.

This mistracking can cause belt damage, and if the belt wander is severe enough, frictional heat and even fires from the belt rubbing on structures or components. Frequent or severe mistracking can result in the belt cutting into the structure. A misaligned takeup can introduce a permanent 'set' or camber in the belt, making it more difficult to keep the belt on the proper path in the future.

Mistracking belts also create a material spillage hazard. Flying or falling material is a risk for workers near the conveyor, and at the same time, this material increases the need for workers to be near the conveyor, performing the maintenance and cleanup chores the fugitive material creates. (**See Chapter 2 Danger Zones of Belt Conveyors.**)

Accumulated on the takeup pulley or mechanism—or on other rolling components—spillage can also lead to more mistracking. This results in increased spillage, which in turn increases fugitive material buildup on components, perpetuating the problem.

Buildup on the takeup weight often comes from conveyor carryback. (**Figure 13.8.**) The takeup weight is calculated specifically for each conveyor design and belt rating. When additional weight is added, whether intentional or not, it creates the potential for early failure in belt splices, pulleys, bearings, and other components, again creating a safety risk.

REGULATIONS AND STANDARDS

All standards focus on guarding the area around takeups to prevent personal injury.

These standards tend to be not very specific; most commonly the takeup is included in the regulation's general 'all moving parts that pose a risk to workers shall be guarded' language.

The following are examples of these regulations.

Australia

The Australian/New Zealand standard *AS/NZS 4024.3610:2015 Safety of machinery – Conveyors – General requirements* discusses "Control of take-up" in 2.6.1.3. This clause notes that controls shall be accessible from outside the guarded area; this refers to power-operated takeups, and so does not apply to gravity takeups with no control mechanism.

The standard continues by requiring that manually operated tension devices, not allow free-wheeling under any condition and these devices shall be accessible from outside the guarded area. Where a power-operated takeup is automatically controlled, the system should provide an option for a manual operation with isolation of the automatic operation.

The standard specifies that wire ropes used for takeup counterweight systems should have a dynamic safety factor of 2.25 and a 4.5 factor for maximum static load.

Passages in the Australian standard *AS/NZS 4024.3610 General Requirements* are concerned with precautions for energy stored in the takeup to allow maintenance. Clause 2.4.2.5 highlights the need for safe access to the takeup as well as a method for securing any energy stored in the takeup be included in the system. A similar thought is presented in 2.6.1.2.2 Gravity take-up isolation, which requires a way to secure any takeup weight to assure the safety of service procedures.

In its discussion of "Hazardous situations and parts requiring safeguards," the *AS/NZS 4024.3610* standard includes takeups in its list of situations that need safeguards. In clause 2.13.2.7, it notes that safeguards should be in place to prevent harm from takeup components, including the winch, ropes, tension carriage, or weight.

The conveyors for bulk materials standard *AS/NZS 4024.3611-2015* echoes that requirement in 2.10.2(d), where it includes takeup pulleys in its list of nip and shear points that shall be guarded on all conveyors.

Brazil

Brazil's *NR-12 Safety in Machinery and Equipment Work* notes in section 12.85:

> The hazardous movements of the continuous material conveyors shall be protected, especially at the crushing, gripping and trapping points formed by the tracks, belts, rollers, clutches, brakes, pulleys, samplers, flywheel, drums, gears, racks, chains, guides, aligners, *stretching region* and *counterweight*, and other moveable parts accessible during normal operation. [Italics added – Ed.]

Section 12.88 follows with:

> The wire ropes, chains, slings, hooks and other suspension or traction elements and their connections shall be adequate for the type of material and sized to withstand the stresses.

Brazil Standard *NR-22 – Safety and Occupational Health in Mining* merely calls out in section 22.8 Belt Conveyors:

> 22.8.2 The design (sizing) and construction of belt conveyors should take in consideration the belt take-up system to ensure a proper tension for safe operation, as specified by the project.

Canada

Section 3 *Conveyors in Occupational Health and Safety In Mines Regulation (O.C. 1236-98, S. 1)* notes:

> 373. Every conveyor shall:
>
> (1) ... have head, return, drive and tension rollers that are protected by a device extending at least 0.9 m (3 ft.) beyond each recessed point;

Under the *Occupational Health and Safety Act, Revised Regulations of Ontario, 1990, Regulation 854 Mines and Mining Plants,* section 196 specifies:

> (2) A conveyor shall have,
>
> (d) … head, tail, drive, deflection and tension pulleys guarded at any pinch point that is or may become accessible.
>
> (3.1) a guard for a pulley referred to in clause (2) (d) must extend at least 0.9 meters [≈3 ft] from the pinch point.

Europe

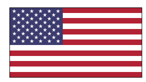
European standard *DIN EN 620 Continuous handling equipment and systems – Safety and EMC requirements for fixed belt conveyors for bulk materials* section 5.1.2.3 Take-up Devices states the following:

> At gravity take-up devices the counterweight, and any other equipment which moves when tensioning the conveyor belt, shall be safeguarded by fixed enclosing guards or fixed distance guards in working and traffic areas.
>
> If the space directly under the counterweight of a gravity take-up device is not safeguarded by fixed enclosing guards or fixed distance guards, then the counterweight shall be fitted with a safety device(s), e.g. brakes, mechanical locking devices, to control the descent of the weight in the event of failure of the belt, suspension rope, chain etc. A safety clearance of at least 2.5 m [≈99 in.] above this traffic area shall be provided. …
>
> Take-up devices that are manually adjusted shall be designed to enable their adjustments to be made from outside the guards. Where the guards have to be removed to make adjustments, interlocking guards shall be provided.
>
> Where horizontal takeup devices are designed to operate automatically, fixed distance guards shall be provided, over the full length of travel, to prevent danger points being reached.

India

Indian standard *IS 7155-2 Code of recommended practice for conveyor safety, Part 2* specifies in section 3.2.1:

> Counterweight tension devices shall be guarded at points normally accessible to personnel. Guards shall prevent access to the space directly below the counter-weight; in the absence of these guards, sustaining devices shall be provided, giving a clearance of at least 2.5 m [≈99 in.] above ground or other operating level.



United States

In its *Data Sheet #569 Belt conveyors for bulk materials Part 1*, the U.S. National Safety Council says:

> Nip points at the head, tail and takeup pulleys should be completely guarded. The sides of each belt should be enclosed far enough back along the run (at least 36 inches) [≈915 mm], so no one can reach in, over or around to contact the nip between belt and pulley.

In section 5 General Safety Standards, *ASME B20.1-2015 Safety Standard for Conveyors and Related Equipment* notes the following:

> 5.8 Counterweights
>
> When counterweights are supported by belts, cables, chains, and similar means, weights shall be confined in an enclosure to prevent the presence of personnel beneath the counterweight. As an alternative, the arrangement shall provide a means to restrain the falling weight in case of failure of the normal counterweight support.

In its section 6 Specific Safety Standards, 6.1 Belt Conveyors – Fixed in Place, 6.1.1 Safety Considerations, *ASME B20.1-2015* notes:

(a) Nip and shear points shall be guarded. Typical locations are:

(1) at terminals, drives, take-ups, pulleys, and snub rollers where the belt changes direction

(c) Take-up mechanisms may be guarded as an entity by placing standard railings or fencing around the area with suitable warning signs, as an alternative to guarding individual nip and shear points.

MSHA offers no specific takeup-oriented regulations, outside of its 'usual' requirement for the guarding of moving machine parts, including takeup pulleys, as discussed in *30 CFR 56/57.14107 (a)*.

The General Industry Safety Standards MIOSHA-STD-1114 from the State of Michigan Occupational Safety and Health Administration includes the following section in Part 14 Conveyors:

R 408.11422 Counterweights:

(1) A counterweight and its pulleys shall be enclosed pursuant to rule 730(2) of the occupational safety standards commission standard, Part 7. Guards for Power Transmission, being R 408.10730(2) of the Michigan Administrative Code.

(2) A counterweight and its pulleys suspended more than 7 feet [≈2.1 m] above the floor or ground, in an area where an employee could walk, shall have an enclosure around the area of impact or a catch pan under the counterweight of such strength and design to hold the counterweight and pulley from dropping to the ground, floor or platform.

(3) A counterweight attached to an arm shall have a bolt fastened near the end of the arm or cable or chain attached to the counterweight to prevent its dropping off the arm.

In *MIOSHA-STD-1108 General Industry Safety Standards,* Part 7 Guards for Power Transmission, R408.10730 provides the following requirements:

(1) A suspended counter balanced belt tightener and its parts shall be provided with a safety cable or device to prevent the tightener from being exposed to contact if the belt breaks or they shall be guarded pursuant to R 408.10751 to R 408.10754.

(2) A suspended counterweight exposed to contact or a part of a counterweight which could subject an employee to injury shall be guarded pursuant to R 408.10751 to R 408.10754 or shall be provided with a safety cable or device to prevent a fall.

The Mine Safety and Health Administration's (MSHA) *Guide to Equipment Guarding*, published in 2004, provides this additional suggestion: "Precautions such as a barricade, railings or a guard should be taken to prevent access below the suspended load." (**Figure 13.9.**)

Figure 13.9.

A gravity takeup and the area below the suspended load should be enclosed in a guard to prevent access.

Photo courtesy of United States Mine Rescue Association.

2

2

BEST PRACTICES

Because the nature of the takeup is to wrap the belt around a pulley and enable that pulley to move to control belt tension, it is obvious that these systems will create nip point hazards. Therefore, they must be properly guarded to shield workers from any expected or unexpected movement of the mechanism.

- All standards require barrier guards around the moving components of takeups. These guards should comply with the Best Practices for Guarding Moving Parts. (**See Chapter 10 Guarding.**)
- Engineered energy-absorbing systems should be incorporated in all takeup designs to control movement of the takeup should the belt or wire ropes break.
- Takeups should never be considered guarded by location.
- No vehicular or foot traffic or equipment or occupied spaces are allowed underneath or near the takeup mechanism.
- The adjustment mechanism for a manual takeup must be designed so adjustment is done outside of the guard.
- Both the travel path of the automatic takeup and the area underneath the takeup weight must be guarded.
- If wire rope systems are used, considerations must be given to guarding for both normal wire rope movement and for controlling the movement should the rope or its supporting sheaves fail.
- The length of the carriage should be at least 2.5 times the belt width to maintain alignment of the takeup pulley.
- The space between the carriage and the structure guides should be controlled using low-friction sliding contact or rollers.
- Consideration should be given to absorbing the kinetic energy of a falling takeup weight and for protecting the surrounding area from the potential of flying or falling debris.
- The structure guides should be designed and maintained vertically and in alignment with the terminal pulleys.
- The takeup pulley and guides should be protected from fugitive material that can get on the clean side of the belt by installing a V-plow on the dirty side of the belt ahead of the first incoming bend pulley.
- The takeup weight (or carriage) should be protected from buildup of fugitive materials with a sloped roof or other deflector.
- Lagging the takeup pulley will help control belt tracking.
- Consideration should be given to controlling the reaction of a broken belt on inclined and declined belts. (**See Chapter 7 Holdbacks.**)

CLOSING THOUGHTS
Takeup the Topic of Safety

Due to the forces of belt tension, the stresses on other takeup components including wire ropes and suspended weights, and the ability of the takeup to move suddenly, it is very important that takeup mechanisms be properly engineered and carefully guarded. Longer conveyors in particular are subject to dynamic reactions which must be taken into account in takeup design and operation. Taking appropriate precautions will go a long way toward improving worker safety around the conveyor takeup. ⚠

Chapter 14

Protection from Falling Material

Photo courtesy of http:// fallarrestsafetynets.com.au/

INTRODUCTION

The flight decks on aircraft carriers have safety nets installed on their edges to catch sailors who fall off the edge or who must jump to avoid hazards such as landing planes or exploding ordinance. Many elevated construction projects have nets to catch workers who might lose their balance and fall.

A similar function is performed by conveyor nets. Nets are installed to catch any material that falls from a belt conveyor and so risks injury to workers, vehicles, or plant equipment. (**Figure 14.1.**) Netting systems are well suited for use on overhead conveyor systems where there is a risk of cargo falling.

If cargo is loaded too near the edge of the belt, or the conveyor suddenly stops or starts, (or both), the change in belt motion can push, project, or slip material off the side of the belt. However, properly positioned conveyor 'catcher' nets will capture the falling material to increase worker safety.

The Hazard of Falling Materials

Bulk-material conveyors handle a wide variety of material sizes and shapes. A cargo can change properties significantly during transport and processing. Design standards take into account the lump size but generally do not take into consideration the material shape. Certain shapes such as round and elongated are very prone to spilling from the moving conveyor along its entire length. Some material forms, such as pellets, will flow or move freely on inclined and declined conveyors. Equipment that feeds conveyors, such as apron feeders and crushers, will sometimes feed unevenly. Some materials will combine (agglomerate) to form masses larger than standard size tests or material specifications would indicate.

All of these issues can lead to uncontrolled or random material movements which turn into spillage and falling material. Controlling the spillage that creates falling or flying bulk materials is a basic design consideration for the safe operation of belt conveyors.

Many conveyors carry large lumps. In mining, the specification for the output from a typical primary crusher is '200 minus.' For system design purposes, a '200 minus' material should be considered to have lumps up to 200 × 200 × 500 millimeters [≈8 in. × 8 in. × 20 in.] in size. Depending on the bulk material density, these lumps could easily weigh 20 kilograms [≈45 lb]. Such a lump ejected from a conveyor traveling 5 meters per second [≈1,000 ft/min] would have a kinetic energy of 250 joules [≈184 lb-ft].

According to a consultant's online publication *Kinetics…a part of Law Enforcement*:

> In the 1970s, the U.S. Army Land Warfare Laboratory conducted research and published a report on blunt impact weapons which resulted in a finding that impact energies between 30 and 90 foot pounds [≈41 to 122 J] are 'dangerous', i.e. contusions, abrasions, broken ribs, concussions, loss of the eyes or superficial organ damage, whereas 'severe damage' occurs if impact exceeds 90 foot pounds [≈122 J], this 'Severe Damage' includes serious skin lacerations, massive skull fractures, rupture of the heart and kidney, fragmentation of the liver, and hemorrhages.

The 250 joules [≈56.2 lb-ft] of impact resulting from the falling or flying lump of '200 minus' conveyor cargo is more than sufficient to cause serious bodily injury.

Another way to look at the need for falling material protection is to compare the impact forces produced by relatively small falling objects to the forces that can damage a protective helmet (hard hat). A common hard hat is expected to absorb approximately 5,000 newtons [≈1,124 lb-ft] of force. The energy needed to produce that 5,000 newtons [≈1,124 lb-ft.] impact is produced by a 5 kilogram [≈11 lb] object falling 1 meter [≈39.5 in.] The same impact can be produced by a 1.25 kilogram [≈2.7 lb] object falling 4 meters [≈13.1 ft]. To weigh 1.25 kilograms [≈2.7 lb], a lump of coal could be as small as 75 x 75 x 230 millimeters [≈3 x 3 x 9 in]. (**Figure 14.2.**) In short, even a small lump does not have to fall very far to transmit enough energy to cause serious, perhaps even fatal, injury.

For all bulk materials, the conveyor loading and discharge zones are prone to creating spillage, leakage, and dust which can fall and create a direct and immediate hazard. The material can also accumulate on the conveyor structure and components and create a latent hazard that may collapse as large masses without

Figure 14.1.

Nets to capture falling material should be installed under conveyors when the belt passes over work spaces or travelways.

Photo courtesy of http://fallarrestsafetynets.com.au/

2

warning, even when the conveyor is stopped.

Fallen material can also accumulate on walkways where it creates a trip and fall hazard. In some cases, it may be useful to provide a structure that serves as an umbrella over a walkway and directs any falling material into a collection area from which it can be easily removed.

The failure of conveyor components is a second major consideration to guard against falling or flying objects. Falling return-idler rollers present a hazard if they become dislodged from their brackets or wear into two pieces. Welded or bolted components, such as wear plates, can come loose and fall, causing injury to personnel or leading to damage to the belt and other components leading in turn to additional injury risks.

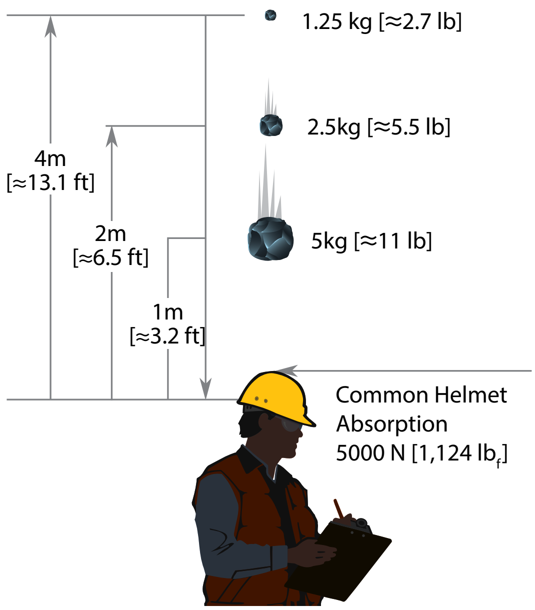


Figure 14.2.

When a lump of sufficient size falls a sufficient distance, it can exceed the impact rating of a conventional hard hat. (Not to scale)

Figure 14.3.

In this installation, the net is suspended well below the conveyors, allowing a greater fall distance.

Figure 14.4.

A roller falling from an idler set punched a hole in this building roof; it could have caused serious injury or death.

Photo courtesy of Dick Stahura, Jr. and Larry Engle.

Catching Lumps, Protecting Workers

Nets are a form of guarding installed to protect workers (and equipment) from bombardment by fugitive material spilling off conveyors. (**Figure 14.3.**) For a number of reasons, spillage is a problem on many bulk-handling conveyors. But it is a greater safety risk on those conveyors which are elevated and which cross above walkways, roads, and work areas.

This is not to say the workers or the work areas could not be covered by roofing, shields, or barriers of some other type. However many roofs, particularly corrugated metal sheets often seen over in-plant maintenance work areas, are not designed to handle impact loads from larger falling objects. There have been incidents where return idlers have fallen from conveyors and penetrated roofs; some have resulted in serious injuries. (**Figure 14.4.**)

The installation of 'lump-catching' safety nets offers some advantages. Suspended below the conveyor on a more or less horizontal plane, these nets contain the spills as well as protect workers. Properly sized and installed, the nets will catch the larger lumps while allowing smaller chunks and fines to fall though. This prevents injury while minimizing the load of material held in the net. (**Figure 14.5.**)

The downside of catching very small particles is that the weight contained in the net will grow more rapidly. As a result of a very tight mesh, the net and structure will see more stress, and the net will need more (or sooner) attention to empty.

Consider what equipment and procedures will be required to safely remove lumps from the catcher net, particularly if the net is itself installed at height. It will be hard to determine how often the net will need to be emptied until the netting is in place, although previous cleanup of ground spillage may provide an indication.

A net can be hung close to the conveyor, minimizing the fall distance and impact energy.

The nature of a suspended net gives it some shock-absorption benefit. It cushions and captures the lumps, rather than allowing them to deflect off as they would a sloped metal roof.

The suspended netting absorbs the force of impact, rather than bending and buckling, and so protects the conveyor structure. Unlike metal mesh, netting is flexible and can cope with straights, curves, junctions, and gradients without any breaks or gaps. The flexibility of 'woven' or knotted nets allows a protection system that follows the line of a conveyor perfectly.

Nets as a Form of Guard

Netting systems protect a facility and people from items that can fall from still or moving conveyors. (**Figure 14.6.**) These conveyor nets are similar to those used in building sites to catch debris and construction material. These construction debris nets can have various mesh sizes—typically from 20 millimeters to 100 millimeters [≈.75 to 4 in.]—and strengths to meet requirements.

These nets have been developed to be durable and reusable and are made from high-tenacity fibers. Tenacity is a measure of strength of a fiber or yarn, defined as ultimate (breaking) force of a fiber. Modern synthetic fibers, such as polypropylene and polyamide, are incorporated in many industrial safety (fall arrest) nets. Therefore, these fibers should provide effective and durable performance in application as conveyor spillage netting.

Using Chain Link Fabric as Nets

An alternative to fabric nets that can be used to catch falling material would be chain link fabric—the wire mesh used in chain link fences. There are a number of reasons chain link fabric can be successfully installed as a falling object 'catcher' netting, including:

- It is rugged, durable, and suitable to withstand many materials and challenging conditions.
- It is readily available with a variety of opening sizes, from ½ by ½ inch up to 3 by 5½ inch [≈12 by 12 mm up to 75 by 140 mm].
- Available materials include mild, galvanized, and stainless steel wire in several gauges.
- Standard fabric, 11 gauge 2 x 2 inch [≈50 by 50 mm], mesh passes the deflection test standard for guarding.
- Many workers have experience with chain link fabric.
- Components for making modular frames are readily available.

Chain link fencing is usually used elsewhere in the plant/mine/facility, which will aid in the

Figure 14.5.

In this installation, larger lumps were captured by the net, but smaller particles fell through the net to the ground.

Photo courtesy of http://fallarrestsafetynets.com.au/

Figure 14.6.

Netting is installed to protect a facility and its people from items that fall from a conveyor.

2

standardization of guards and the immediate (in-house) availability of the materials. (**See A Recommendation: Chain Link Fencing as a Falling Material 'Net.'**)

Net or Screen Box?

While most 'catcher nets' are suspended at the point of need—that is, where material is most likely to be tossed from a moving belt—there are systems available where an entire conveyor can be shielded in a box of screening. (**Figure 14.7.**) One supplier offers a three-sided box construction that is 3 feet [≈900 mm] on each side that will cover a conveyor section 25 feet [≈7.6 m] long with one inch [≈25 mm] mesh; perhaps similar systems could be developed for wider belts. These systems were conceived for roller conveyors in warehousing operations, but might work well for protecting workers around the belt conveyors handling bulk materials especially in confined (or indoor) spaces.

Specifications for Netting

Fabric mesh is available in several sizes from 100 by 100 millimeters [≈4 by 4 in.] down to 10 by 10 millimeters [≈0.375 by 0.375 in.] or smaller. Chain link fabric is available with openings from as small as ½ by ½ inch up to 3 by 5¹/₂ inch [≈12 by 12 mm up to 75 by 140 mm]. As noted above, smaller mesh will catch more material and, as a result, fill up and need to be emptied sooner.

A netting supplier should be able to provide various specifications for a given net. The specification should include fiber type(s) and the size of the 'string' used in weaving the net, the load rating of the net, and the details of the edge binding. The supplier should also offer guidance on the attachment of the net to the conveyor structure.

Installed nets should certainly be inspected for condition and performance at regular intervals. Nets can often be purchased with additional 'sacrificial' test meshes that allow periodic strength testing.

REGULATIONS AND STANDARDS

In most cases, established conveyor safety standards say workers must be protected from falling or flying material, but these standards give little guidance as to how to accomplish that task. Published standards for safety nets are generally concerned with fall arrest netting for personnel working at heights, and so have

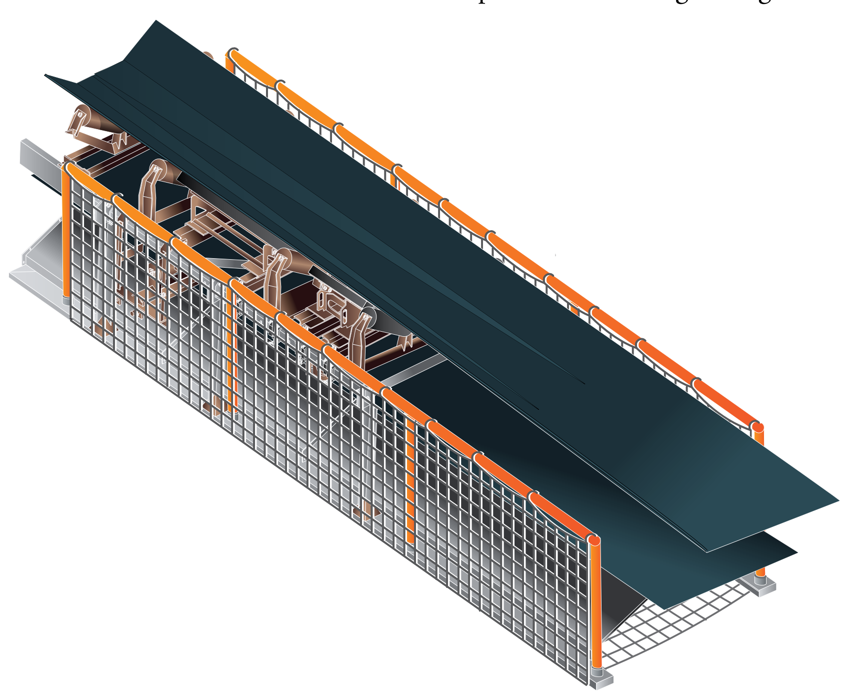


Figure 14.7.

A 'box' created of netting can be installed around a conveyor to capture falling cargo and components.

2

little application to the netting which is used to catch falling conveyor cargo. (**Figure 14.8.**)

However, it is a general requirement to protect workers from being subjected to material falling from conveyor belts.

Australia

The Australian/New Zealand standard *AS/NZS 4024.3610:2015 Safety of Machinery – Conveyors – General requirements* contains requirements for the reduction of safety risks by the containment of spilled material. In clause 2.13.2.6, it notes that where conveyed material can fall or be thrown into an area accessible to workers, safeguards should be required. When considering what types of guards to provide, the clause states that the physical properties of the conveyor and cargo—such as lump size and mass, belt speed, and height of the conveyor—shall be reviewed.

Section 2.13.2.1 similarly notes that safeguards should prevent materials from falling on or being thrown onto persons.

In a discussion of underpasses, section 2.4.2.3 likewise notes that conveyors should be guarded to prevent rock falling onto workers traveling underneath the conveyor.

Brazil

Protection from material falling from conveyors is provided in two standards in Brazil:

NR-12 Safety in Machinery and Equipment (section on Material conveyors):

> 12.90.2-3
> The presence and circulation of persons under the continuous conveyors are only allowed in protected locations that have adequate size and strength against falling of materials. [The preceding translated section is edited for clarity in English.]

NR-22 Safety and Occupational Health in Mining (section 22.8 Belt Conveyors):

> 22.8.5
> Traffic under belt conveyors will only be permitted in areas protected against falling materials.
>
> 22.8.9
> Elevated conveyors must contain safety devices installed where there is risk of materials falling or being launched in an uncontrolled way.

Canada

Under the *Occupational Health and Safety Act, Revised Regulations of Ontario, 1990*, Regulation 854 Mines and Mining Plants, section 196 (4) notes:

> Guards shall be provided beneath a conveyor:
>
> (a) that passes over a worker; or
>
> (b) from which falling materials or parts may endanger a worker.

In section 3 – Conveyors *Quebec's Occupational Health and Safety in Mines Regulation (O.C. 1236-98, s.1) Revised Regulations of Quebec*, requires,

> 373 Every Conveyor shall: …
>
> (2) be equipped with a device that prevents any object or materials from falling, where the conveyor is installed above a place where workers move about; (O.C. 119-2006, s.25)

Figure 14.8.

Netting should be installed under belts to protect workers below the conveyors.

Photo courtesy of http://fallarrestsafetynets.com.au/

Europe

In section 5.1.5.2 Handled Materials, *DIN EN 620:2011-07* states:

> The whole conveyor path, especially the loading, unloading and transfer points, shall be designed to minimize the risk of spillage of materials.
>
> To minimize problems due to spillage, particular attention shall be paid to head and tail pulleys, especially the latter, where there may be problems due to material inadvertently carried on the return side of the conveyor belt.
>
> Where a conveyor passes above working or traffic areas, suitable protection shall be provided against falling of conveyed materials or debris depending on the type of material handled e.g. by a protection plate, wire mesh …
>
> The installation shall be designed so that it can be easily cleaned. If materials can adhere to the belt, a device shall be provided to prevent the ingress of material at nip point(s). These devices shall be designed so that there is no danger of material falling into working or traffic areas, e.g. using collection chutes, boxes etc.
>
> Conveying equipment shall be designed to avoid conveyed materials slipping back or falling off, taking account of the intended use.

India

Indian standard *IS.7155 (Part 2)-1986* presents the requirement in at least three areas:

> 3.1.22
> Overhead gantry portion of road and rail crossings, walkways, galleries, work places under the overhead conveyors used by the personnel, shall be protected by means of suitable covering such as plates/steel sheet covers to prevent the falling of material/objects over such areas/personnel.
>
> 3.2.10
> Where the appliances pass above work stations or passageways, suitable protection shall be provided against accidental dropping of conveyed materials.
>
> 3.2.21.2
> At points along a conveyor where material is likely to become dislodged and in falling become a hazard to persons, suitable guards or nonreturn flaps shall be provided.

United States

In the United States, several regulatory agencies call for measures to prevent accidents and injuries from material falling from conveyors. In its *Safety and Health Standards – Surface Metal and Nonmetal Mines*, published in *30 CFR Part 56* and *57*, Mine Safety and Health Administration (MSHA) notes:

> 56.14110/57.14110
> Flying or falling materials.
> In areas where flying or falling materials generated from the operation of screens, crushers, or conveyors present a hazard, guards, shields, or other devices that provide protection against such flying or falling materials shall be provided to protect persons.

OSHA regulations are similar; *29CFR 1926.555 (a)(5)* notes:

> Where a conveyor passes over work areas, aisles, or thoroughfares, suitable guards shall be provided to protect employees required to work below the conveyors.

ASME B20.1-2015 Safety Standard for Conveyors and Related Equipment, contains an even more general statement:

> 5.9.2 Guarding by Location or Position …
>
> (d) Although overhead conveyors may be guarded by location, spill guards, pan guards, or equivalent shall be provided if material may fall off the conveyor and endanger personnel.

A similar passage is contained in 5.13 Transfer, Loading, and Discharge Points:

(a) At transfer, loading, and discharge points where unconfined and uncontrolled free fall of material can result from flooding, ricocheting, overloading, trajectory, leakage, or a combination thereof, such unconfined and uncontrolled free fall of material shall be prevented if it would create a hazard to personnel.

In *WAC 296-806-42020*, the State of Washington Administrative Code notes the following requirements for spill guards:

You must:

- Install protective or spill guards wherever conveyors pass next to or over working areas or passageways.
  - These guards must be designed to catch and hold any materials that may become dislodged or fall off.

BEST PRACTICES

Protection from Falling Material or Components

- De-rate the conveyor capacity to minimize issues with intermittent or surge loading.
- Design the conveyor so that the belt is not inclined more than 5 degrees at the loading point to reduce the chance of material rolling or sliding back.
- Run the conveyor at no more than the designed carrying capacity.
- Maintain crushers and other process equipment so that cargo lumps are no greater in size than specified in the conveyor design.
- Make loading-zone skirtboards long enough to allow material to settle before leaving the chute extension.
- Provide guards or deflectors that will contain falling or flying materials at the transfer points.
- Provide guards or nets that will capture any falling lumps along the run of the conveyor.
- Provide area guards along the conveyor run to prevent people from walking under the conveyor except at designated and guarded crossings.
- Provide catch baskets for return rollers when the conveyor passes over travelways, buildings, or other areas accessed by people.
- Use a V-plow or diagonal plow in advance of the belt's return into the tail pulley to steer material off the belt into a defined and guarded location, while preventing material from being thrown by the rotating pulley or moving belt.

Characteristics of the Netting

The net should be:

- Big enough to cover the area where a lump might fall or deflect (off the structure) on its way down; the closer to the conveyor the net is installed, the smaller it can be in overall size. It is a good practice to oversize the net, as the material landing point(s) may be much different than originally predicted due to changes in material speed, trajectory, or structural configuration.
- Strong enough to catch and hold the largest object that might be conveyed. This can be evaluated against the calculated kinetic energy, defined by maximum lump size and mass at the local fall distance.
- Able to withstand the impact of a large lump, even when already loaded with one or more large lumps. The method of attachment and the structure to which the net is attached should withstand the weight of a net full of bulk material.
- Able to withstand sharp edges. Some tear-resistance (or 'rip stop' capability) will extend the life of the net.
- Able to perform in the environment to which it will be subjected. Nets are subject to abuse from the conditions of their

installation, including weather, sunlight, temperature extremes, insects, animals, and exposure to industrial chemicals, pollution, and dirt.

- Small enough mesh to capture lumps of any size that might lead to significant injury to workers or pedestrians in the impact area.

Characteristics for Installation of Nets

Installation best practices include:

- 'Catcher' nets should be installed as close as possible to the level of the conveyor.
- Nets should be suspended below the conveyor and installed on a more or less horizontal plane. Lumps will bounce and slide toward the low end of the net and could impact conveyor structure or other components during this delayed descent. Material in nets will move toward the low end of the net, both during their initial descent, and as a result of the impact of subsequent lumps.
- Nets should be positioned to catch debris falling with movement in any direction. That is, cargo will fall from the belt with movement in the direction of the conveyor transport, in the opposite direction of conveyor movement, or to either side of the belt.
- Nets should only be installed where there is sufficient room below the net so that the net can distort from the impact of lumps. This will absorb the shock without risk for workers, or damage or undue abrasion (from the lump or from the ground) to the net.
- Some thought should be given as to how the net will be unloaded after it is holding some lumps.

Figure 14.9.

A 'catcher net' is installed along the run of this overhead conveyor.

Image courtesy of http://fallarrestsafetynets.com.au/

CLOSING THOUGHTS
The Net Results

Conveyor nets are a simple solution to protecting workers from injury and saving equipment from damage or loss. (**Figure 14.9.**) As seen above, most of the conveyor safety standards do not specifically call for netting; the application of nets and other barriers has proven to be an effective method for containing the random fall of spilled material and so lessen the risk of injury around belt conveyors.

However, it is worthy of some consideration that if there is a significant, repetitive problem with material spillage along a conveyor, there should be measures undertaken to correct the causes of that spillage.

The causes should be assessed; they could include any or all of the following: structural damage, overloading, poor loading pattern and practices, upstream problems with load placement or lump size, the influence of wind and weather on the belt, or belt wander from other causes. The operation should then consider correcting those problems to reduce the need and reliance on netting.

Netting is available from commercial suppliers in many materials and specifications; a reputable supplier can help develop the selection of an appropriate net. Whether the conveyor system is located at near ground level or overhead, 'catcher' nets are a workable answer to the problems of falling cargo.

Nets are an effective and common solution, but they usually do not cure the root cause of the hazard. 'Catcher' nets represent a bandage, rather than a cure for problems with material spillage. ⚠

2

A Recommendation: Chain Link Fencing as a Falling Material 'Net'

Rather than fabric netting, one form of guard to use to reduce the hazard of falling materials is chain link fencing installed parallel to the stringers. This application is compatible with the use of framed chain link fencing as recommended in **Chapter 10 Guarding**.

Chain link fencing—also referred to as wire-mesh fence, cyclone fence, or diamond-mesh fence—can be installed in a horizontal, more or less flat manner to similarly catch any falling material. Installed in this manner, it can provide several advantages over the fabric nets.

These advantages include:

- Fabric meshes may be intended for temporary use and so not stand up to years of sunlight and weather in conveyor applications.
- Fabric nets are also difficult to properly attach to a structure. Zip ties are commonly used, and they too are not load rated and suffer from environmental degradation.

Suggested chain link fence mesh and frame materials (as noted in the Chain Link Fence Manufacturers Institute Product Manual CLF-PM0610 Updated June, 2016) include:

- Frames
  ASTM F1083 Regular grade 1.875 inch [≈47 mm]
  Schedule 40 steel pipe
  30,000 pounds per square inch [≈0.208 MPa] yield strength
- Mesh
  2 inch [≈50 mm] mesh of 6-gauge steel wire
  Nominal wire diameter 0.192 inches [≈4.88 mm]
  Application grade is Commercial/Industrial/Security

Material Finish – Galvanized or Steel Coated

This recommendation is made for the same reason as this publication's recommendation of three mesh sizes, including chain link, for guard panel mesh; standardization reduces the chance of making a mistake in applying the material as a guard.

A 'catcher net' is installed along the run of this overhead conveyor

2

Chapter 15 Conveyors, Belting, and Fires

Credit

This chapter was prepared with the gracious assistance of Geoff Normanton, Senior VP Technology, Fenner Dunlop Americas.

Photo copyright Phil Hearne / Fairfax Syndication.

INTRODUCTION

The Challenge of Conveyor Fires

Conventional belts are easily ignited, spread fire rapidly, and release significant quantities of smoke. For the operations that rely on conveyor belts, fires on those belts represent especially high risks for the safety of workers and for the company's bottom line for two reasons.

The first reason is that conveyors have the ability to spread a fire over long distances. There is a great danger the conveyor with a belt on fire (or cargo on fire) will carry that fire throughout the facility. As Sytze Brouwers noted in an article in *Bulk Solids Handling*, a belt conveyor can "literally 'convey' the fire throughout the site. The consequences can be catastrophic." (**Figure 15.1.**)

A second challenge is that conveyor fires are typically very hard to fight. The belt is a long structure, and the fire can have been spread all along this extended route. The belt path will often run around or through a variety of enclosures and structures all of which contain the risk of catching or sustaining the fire inside them, and which make it harder to combat a fire. In addition, the conveyor structure is often elevated in the air over this extended length.

Conveyor belts—whether made from natural or synthetic rubber or plastics—must be assumed to be capable of self-sustained fire propagation, regardless of the lack or presence of other combustibles. As Brouwers, an applications engineer for a belting manufacturer, noted:

> The top and bottom covers that protect the carcass of the belt and the rubber skim between the fabric plies of the carcass can be engineered to resist fire but the complete structure of the belt cannot be made fire proof. … In other words, every belt will burn when it is exposed to a naked flame that has sufficient energy to ignite the belt.

Once ignited, conveyor belts will produce dense black smoke. The blaze and smoke resemble a tire fire; essentially, that is what it is. (**Figure 15.2.**) The flame and smoke further complicate the tasks of worker evacuation and firefighting.

If a burning belt should split under tension, the burning ends can fly apart leading to two separate fires at different locations, as well as the splatter of a burning rubber sludge.

On a conveyor system, the principal fire load (or potential) is contained in the conveyed material and the belt itself. Combustible cargos include wood chips and scrap wood, grain, sugar, and coal. Burning product can be passed from one belt to the next, spreading the fire. Bulk materials with elevated temperatures, from high temperature processes such as cement or coke, can create risks for the belt and the operation as a whole.

Conveyor enclosures and structures are normally of non-combustible construction. However, any large fire in the conveyor system can lead to damaged structures. Inclined conveyors may create a flue-like effect, increasing the spread of a fire and magnifying the potential for damage.

In an article discussing a 2004 belt fire at Northam Platinum, one South African safety consultant noted, "Once a conveyor fire starts, it soon grows to an event that cannot be easily controlled." (**See The Costs of a Conveyor Fire, in Lives and in Corporate Earnings.**)

Added Concerns in Underground Operations

Belting fires must be of particular concern in underground applications. This is due to the increased hazards of the fire to personnel, and to the increased difficulty in fighting fires in the application's remote areas where there is limited access and restricted or controlled ventilation. As the United Kingdom's Health and Safety Executive's 1993 topic report, *Safe use of belt conveyors in mines*, stated:

> Fires are the greatest hazard associated with underground belt conveyors as they have the potential to cause multiple fatalities. Mines can be compared to offshore oil and gas rigs in their complexity and hazard potential, both having persons and machinery in con-

Figure 15.1.

For operations that rely on conveyor belts, fires on those belts represent high risks for the safety of workers and of the company's bottom line.

Figure 15.2.

Belt fires release dense black smoke making the blaze resemble a tire fire.

Photo courtesy of Greater Eagle Fire Protection District.

2

> fined spaces with potentially hazardous atmospheres. At mines and offshore rigs it can be difficult to escape rapidly from fire and smoke. Additionally, fire below ground creates smoke and possible lethal concentrations of carbon monoxide and other toxic gases which may be carried by the ventilating current through the mine.

In a 2008 paper, *Conveyor belt entry fire hazards and control*, Harry Verakis and Michael Hockenberry of the Mine Safety and Health Administration (MSHA) noted:

> It doesn't take much time for a conveyor belt fire to build in intensity and create a potentially lethal atmosphere. … A conveyor belt that has poor resistance to fire will spread flames along the exposed surfaces of the belt and eventually ignite other combustibles such as the coal.

2

The special hazards with underground belt fires were noted in a 1996 letter from technologists at Monsanto to MSHA (as quoted in a response to *Request for Information RIN 1219-AB60 on Conveyor Belt Smoke and Flame Standards*):

> Smoke effects are greatly amplified in an underground mine where visibility, escape routes, and access by rescuers are already severely limited. This situation is further worsened by the growing practice of using 'belt air' to ventilate the mine face.

As the *Safe use of belt conveyors in mines* report noted:

> Even a short-lived fire [underground] can endanger persons remote from the fire as belt conveyors are predominantly in intake airways and all persons on the return side are at risk.

Impact of Conveyor Belt Fires

The problems created by conveyor fires are quickly manifested in many ways.

The Aracoma Mine Fire: Frictional Heat Leads to Tragedy

On January 19, 2006, the conveyor belt ignited at the Aracoma Alma Coal Mine at Melville in Logan County, West Virginia. Smoke poured through the gaps in the mine walls and into the fresh-air passageway that the miners were supposed to use for their escape, obscuring their vision and ultimately leading to the death of two of them. The two miners died of carbon monoxide poisoning after they had become separated from other members of their crew. The fire was not fully extinguished until January 24, 2006, five days later.

According to the MSHA investigation, the fire occurred due to frictional heating when the longwall conveyor belt became misaligned. This heating, in conjunction with other combustible materials, created the conveyor belting fire.

MSHA tests carried out after the Aracoma fire on two samples of the belting concluded that both met the then-current requirements of the MSHA laboratory fire test standard *Title 30 CFR 18.65* (commonly known as Schedule 2G). The samples did not meet the more rigorous Belt Evaluation Laboratory Test (B.E.L.T.) standard which had been proposed by MSHA in the late 1980s but never implemented. The B.E.L.T. standard has now been adopted.

Citing friction as the source for ignition of this belt fire is consistent with general industry data. According to a 2008 presentation, *Conveyor Belt Entry Fire Hazards and Control,* by MSHA's Harry Verakis and Michael Hockenberry to the U.S./North American Mine Ventilation Symposium, of the seven conveyor belt fires in the United States between January 1, 2006, and May 16, 2008 (including the Aracoma fire), analysis shows that three (≈43 percent) were caused by frictional heating along the conveyor belt, and an additional one (≈14 percent) originated in rollers or bearings.

First, of course, belting fires have resulted in severe injuries and loss of life. In addition, fires have significant financial impact on the operations in which they occur. One insurance company has listed the costs for fires directly involving conveyor belts as costing an average of nearly $8 million (USD) per claim.

Sparks from welding led to a million-dollar conveyor belt fire at a coal-fired power plant in Colorado in 2013. More than 300 feet [≈91 m] of belting was on fire when the fire department arrived at the scene. A secondary fire was created when pieces of burning belt fell into the plant's coal stockpile. The firefighting effort was complicated by the location of the fire on the conveyor structure over 180 feet [≈55 m] above the ground. (**Figure 15.3.**) Initial estimates placed damages at the $1 million (USD) mark; fortunately, no one was injured. As reported by *KRDO.com*, the fire was attributed to sparks from contractors welding on the conveyor system.

In the 2008 paper, *Conveyor belt entry fire hazards and control*, MSHA researchers Harry Verakis and Michael Hockenberry listed some of the areas where these adverse financial impacts are felt, including:

- Lost production days
- Costs for extended work hours
- Extinguishment costs for chemical agents and equipment
- Costs of sealing a section of the mine or mine itself
- Costs for rehabilitation of the affected area(s)

According to Verakis and Hockenberry, the belt fire at Bethlehem Steel's Marianna Mine in March 1988 is estimated to have cost five to six million dollars for the firefighting efforts alone. This figure does not include the other associated costs, including the eventual closing of the mine.

Causes of Belt Fires

The European Commission's report, *Early detection and fighting of fires in belt conveyor (Edaffic)*, provided a more comprehensive—although as the report itself noted, "non-exhaustive"—list of "possible ignition sources":

- Friction of belts
- Collapsed idler bearing
- Fires of flammable liquids
- Slide of a belt in a drive
- Jammed rollers
- Friction from brake
- Coal spillage
- Excessive temperature of the drive
- Seizing of bearings
- Seizing of gears
- Collapsed pulley bearing
- Sparks, electrical causes
- Friction between belt and construction
- Hot surfaces
- Smouldering fires of coal dust

Frictional heat seems to be the prime cause of belting fires. Fires on belt conveyors are most often ignited by mechanical failures like frozen idlers which are even more dangerous in combination with coal dust. These frictional ignitions are a common source of belt fires, accounting for approximately 20 to 40 percent of all belt fires depending on time period and who was keeping the records. Loss history demonstrates that the belt itself presents a

Figure 15.3.

A belting fire on an overhead conveyor caused major damage at a coal-fired power plant.

Photo courtesy of KRDO-TV.

2

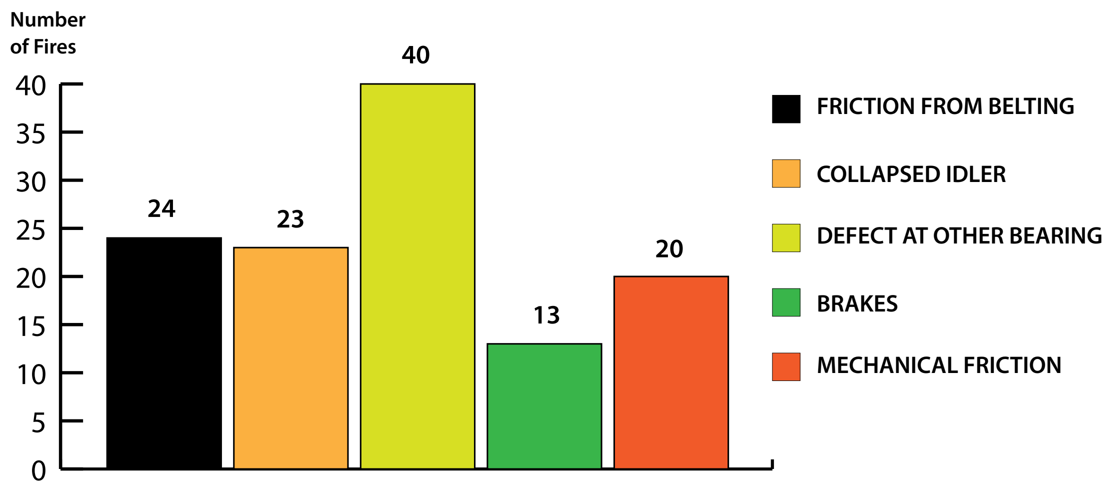
sufficient combustible material to spread the fire without contribution from other fuels.

The *Safe use of belt conveyors in mines* report, a study of underground conveyor fires in United Kingdom coal mines between 1986 and 1991, listed a variety of causes including idler and bearing problems and friction as shown in **Figure 15.4**.

The 2008 presentation, *Conveyor belt entry fire hazards and control*, by Verakis and Hockenberry counted 63 belt entry fires in the United States during the 25-year period from 1980 to 2005. The study indicated friction was the largest cause of belt entry fires. Friction heating accounted for 36 percent of belt entry fires, with half of those (11 fires) coming from

Figure 15.4.

Number and causes of belt fires from 1986-1991, as reported in the HSE Topic report, "Safe use of belt conveyors in mines."



2

The Costs of a Conveyor Fire, in Lives and in Corporate Earnings

A conveyor fire could not only result in the severe injuries and loss of life of workers in the operation, but can also have a significant effect on a mining company's financial performance.

In September 2004, a belt fire more than a mile underground at South Africa's Northam Platinum Mine claimed nine lives. At the time of the fire, the mine had more than 1,000 workers underground. The fire was limited to an area where 55 miners were working; 46 were rescued, nine perished. Initial reports stated the fire was first detected at an underground belt used to transport ore and waste. The nine mineworkers died as a result of asphyxiation from poisonous gases.

The fire halted operations for six weeks at the mine, South Africa's fourth largest platinum producer. Production was halted while investigations into the accident took place with mining resuming in November.

According to an article, "Conveyors come under scrutiny after Northam Platinum fire," by Helene Le Roux in South Africa's *Mining Weekly* newsletter, total revenue losses for the company due to the suspension of operations were estimated at R147 million [≈$25.9 million USD] based on prevailing metal prices and exchange rates. Actual damage to the area affected was estimated at R8.5 million [≈$1.5 million USD].

An article on *mineweb.com*, "Northam Platinum recovers from fire" by Geoff Candy, stated the production stoppage resulted in a 40 percent drop in profits for the company for the six-month period ending December 31, 2004. The company's earnings fell to R62.7 million [≈$11.1 million USD] in the six months ending December 31, 2004, from R104.1 million [≈$18.3 million USD] in the corresponding period of 2003. This led to a dividend reduced to 57 percent of the previous year's rate, paying 25 cents ZAR [≈4 cents USD] for the six months to December 31, 2004, down from 44 cents ZAR [≈8 cents USD] paid for the first half of 2003.

The consequences of the belt fire were significant to all, from workers underground to investors far removed from the mine site.

frictional heat at the conveyor drive and the remaining half of the friction fires caused by friction along the belt. (**Figure 15.5.**) Other causes include "hot roller-bearings" (for example, idlers with failed bearings) which led to 10 percent of the belt entry fires, electrical problems caused 13 percent, and 8 percent originated in cutting and welding work.

As noted in the *Belt Air Technical Report*, during the period from 1990 to 1999 in the United States:

> There were a total of 87 reported fires in underground coal mines. These fires were classified in a variety of ways including by the source of ignition and by the burning material, both of which are pertinent to an assessment of belts as a source of ignition and as a fuel. Of these fires, 15 (17%) resulted from frictional ignition, and for 13 (15%) the belt itself was the principal fuel. The proportion that occurred as a result of frictional ignition was slightly less than the proportion reported from 1970 to 1988 (17% vs. 22%).

FPASA Bulletin SF 10, *Fire Hazards of Belt Conveyors*, issued in April 2000, listed other common causes of belt fires as:

- Cutting and welding activities [that] generate hot molten metal particles which can ignite the belt [cargo] or accumulations of waste below [the conveyor].
- Overheated material from ovens, kilns, or dryers that have not been cooled sufficiently before being placed on the belt.

Friction as a Cause

Heat arising from friction is one—if not the—leading cause of belt fires. This friction can arise in a number of places, but all are basically concerned with the running of the rubber belt into and over the structure or other conveyor components. The added friction creates overheating in the belt drive area or near idlers along the belt structure. When the conveyor belt is stopped, the heat provides the energy to create a fire on the belt. If the conveyor belt has poor flame-retardant properties, the flame will begin to propagate along the exposed surfaces.

A 1981 presentation to the Society of Fire Protection Engineers titled *Fire Protection in Coal Handling Facilities New and Retrofit*, by K.W. Dungan, P.E. noted:

> Statistics in the coal mining industry from 1951 to 1969 indicate that 91 of the 134 conveyor fires reported resulted from friction heating. These normally occur with a slipping belt and a moving drive pulley.

As noted in **Figure 15.4**, 24 of the 120 fires noted in the 1993 *Safe use of belt conveyors in mines* report from the United Kingdom's Health and Safety Executive resulted from frictional heat due to the belt rubbing against the conveyor structure, coal spillage, or other material. An additional 20 fires were the result of idlers or rollers rotating in spillage or against a structure also generating frictional heat. The report noted:

2

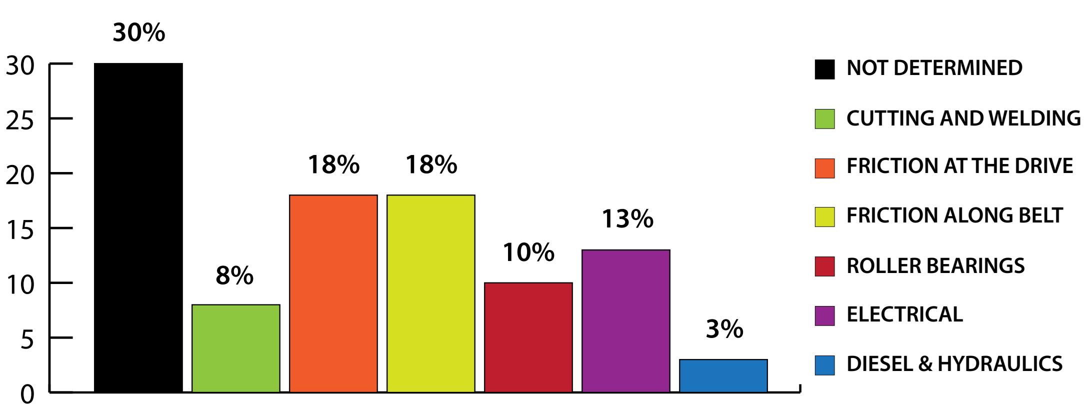


Figure 15.5.

Causes of belt fires as reported in the 2008 Verakis and Hockenberry presentation, Conveyor belt entry fire hazards and control.

> Failed bearings are by far the most common source of conveyor fire ignition, particularly those on bottom idlers where there is more likelihood of contamination and contact with flammable material. Bearings in conveyor idlers manufactured since 1986 have been lubricated with FR [fire-resistant] grease which has reduced the likelihood of bearing fires.

That report continues:

> For current designs of idler, bearing failure … usually occurs before shell wear out, which is significantly less hazardous and more amenable to planned maintenance. … Bearing failure can develop quickly, often within the period between routine inspections, making preventative maintenance difficult.
>
> Where imminent bearing failure is detected [often by a noise made by the bearing], idlers should be changed as a matter of priority.

Dungan's report also noted that defective conveyor brakes can lead to the friction and heat that turns into belt fires.

> All mechanical brakes generate frictional heat when applied and dangerously high temperatures can quickly occur at the brake linings if the brakes are used excessively or if there is inadequate cooling. … Most brake fires occur when brakes are inadvertently applied or not fully released due to maladjustment, inadequate maintenance or dirt.

It is important that mechanical brakes have "adequate thermal capacity to avoid excessive temperatures if the conveyor is stopped repeatedly."

The Creswell Mine Fire

Mine fires in the United Kingdom led to the development of conveyor belt testing and specifications for fire retardance. The most influential impetus was the Creswell Mine Fire of 1950, where 80 men died of carbon monoxide poisoning. (**Figure 15.6.**)

As discussed in the report, *Accident At Creswell Colliery, Derbyshire*, by Sir Andrew Bryan, on September 26, 1950, a major disaster arose from the use of an underground belt conveyor. An outbreak of fire occurred when friction due to debris at a transfer point caused the rubber belting to ignite. At the time of the fire, 131 miners were in the vicinity of the fire; 80 of the workers perished.

Figure 15.6.

The tragic results of the Creswell mine fire helped lead to the development of fire-retardant belting.

Although detected within minutes of starting, the fire spread some 555 meters [≈1,820 ft]—about one-third of a mile downwind—along an intake roadway, according to the Health and Safety Executive report, *Safe use of belt conveyors in mines*.

The NIBA Technical Article, *MSHA Conveyor Belt "Final Rule,"* reports investigations:

> ... showed that the cause of the fire was torn belting jamming a delivery chute which was in contact with the moving belt. Frictional heat developed at this point initiating the fire.

This disaster in turn led to one of the first standards for conveyor belting: *National Coal Board Specification P113/1954*. This later became the very well-known standard *NCB 158*. It also became the driver of standards worldwide including the United States Bureau of Mines which led to the introduction of a laboratory flame test generally known as Schedule 2G.

In the United States, the *Federal Coal Mine Health and Safety Act* specified that after March 30, 1970, all conveyor belting acquired for use in underground coal mines would be fire-retardant. The safety regulations promulgated to implement the mandate of the 1969 act specified that belt be approved under *Title 30, Part 18, section 18.65* (also known as Schedule 2G).

According to the article, *Reducing the Fire Hazard of Mine Conveyor Belts*, by Harry C. Verakis of MSHA, during the 19-year period from 1970-1988, there were 39 belting fires reported to MSHA. Seventy-five percent occurred in mainline belt entries. There were increasing numbers of fires in the last six years of the period, fires which burned as much as 610 meters [≈2,000 ft] of belting and caused injuries and a fatality. As a result, a program of improving belting fire safety was undertaken by MSHA in conjunction with the United States Bureau of Mines. This led to the development of the Belt Evaluation Laboratory Test (commonly B.E.L.T. or BELT), which was proposed but not enacted until 2007.

Determining the Fire Retardance of Belting

Conveyor belt fire-retardance standards are based on the premise that a belt should never be the cause of a fire, should be difficult to ignite, and, if ignited by an external fire source, should not propagate the fire. In response to the need to establish standards for fire-retardant belting and the concomitant need to demonstrate the achievement of these standards, a series of tests were developed.

Over the last several decades, the testing standards have focused on four main test requirements, which in turn have generated testing procedures. In no particular order, these requirements are:

- The belt surface should be sufficiently conductive to prevent the buildup of a static electric charge.
- The belt should resist catching fire due to friction (as with a drum rotating under a stalled belt).

Is it Retardant or Resistant?

Conveyor belts cannot be totally fireproof.

Under the proper set of conditions (or perhaps, under the worst case conditions) every belt, even those with the highest ratings for fire retardance will burn and even propagate flame. The elastomeric components of belting can be formulated to resist fire, but cannot be made fireproof.

A working definition for this volume is that fire-resistant means hard to ignite and fire-retardant means does not burn well and/or is self-extinguishing. *Wikipedia* notes, "Whilst a fire resistant material is one that is designed to resist burning and withstand heat, fire retardant materials are designed to burn slowly."

Lawyers may have a different opinion, or at least an opinion they will justify in the pursuit of damages. But we are not lawyers, and so for the purposes of this volume, we will use the terms 'resistant' and 'retardant' as interchangeable.

Similarly, the words 'flame' and 'fire' will also be considered synonymous here.

- The belt should be difficult to ignite (when faced with open flame).
- An ignited belt should not propagate (spread) a fire; for example it should be self-extinguishing.

These procedures have resulted in belting that has prevented the fires on the scale seen in the 1950s by preventing ignition and propagation of fires developed from external sources and from frictional heating.

Fire testing of conveyor belting is complicated. The detailed protocols can require large pieces of belting, controlled methods of burning and sophisticated measurement systems. Even the smoke from the test procedures must be carefully filtered to comply with air pollution control standards.

Testing for Static Discharge

A conveyor belt passing over a pulley or idler can create a static charge. The discharge of static electricity can reach the energy levels necessary to ignite some dusts.

It is best to avoid the buildup and subsequent discharge of static electrical charges from moving conveyor belts. In those operations where coal, gas, fertilizer, grain, or other potentially combustible materials are present, it is important that belting not build up static electricity that can generate a sparking discharge with possible ignition of dust or methane that creates a fire or explosion.

Figure 15.7.

Static discharge test.

Photo courtesy of Fenner Dunlop.

According to NIBA Tech Note #9, titled *Static Electricity Considerations*, research by J.T. Barclay of the National Coal Board (NCB) in the United Kingdom in the 1950s established that for belts having surface-resistance values of less than 10^9 ohms, no charge was retained. As a result, the value of $3x10^8$ ohms (300 megaohms) for the surface resistance of conveyor belts was established as a standard; this figure included a safety factor to allow for inconsistencies in belting or conditions.

Electrical resistance is determined by passing an electric current of specified voltage between electrodes placed on the surface of the belt. (**Figure 15.7.**) The test applies a highly regulated, stabilized DC voltage through the belting, measuring the amount of current that flows, and then calculating a resistance measurement using Ohm's Law. The test is normally carried out with samples conditioned to a specified temperature and humidity.

Based on the work by the NCB's Barclay, the internationally-recognized acceptance criteria for belting's electrical conductivity is now established at a maximum resistance of $3x10^8$ ohms ($\leq 300\ M\Omega$) when tested by the method described most recently in *BS EN ISO 284:2012 Conveyor belts – Electrical conductivity – Specification and test method.* By specifying the maximum electrical resistance of a conveyor belt and the corresponding test method, the test ensures that the belt is sufficiently conductive to avoid the accumulation of electrical static charge which can be developed during service use. This test superseded *DIN EN 20284 (1993-05)* and other earlier testing specifications.

This specification has been adopted worldwide in the coal and grain industries, including the United States Occupational Safety and Health Administration (OSHA) standard *29 CFR 1910.272(q)(2)* for belting used in grain-handling facilities.

MSHA does not presently list a static discharge requirement, making the United States the only major mining country that does not have a specific standard and test protocol for surface-static resistance.

Testing for Resistance to Frictional Heating

One cause of conveyor fire arises from a stalled belt and a driven rotating drum or pulley, or alternatively, a belt moving across a stalled pulley. This results in a buildup of heat that can turn into flames.

Consequently, tests were developed to study the resistance of the conveyor belting to ignition and glow or sparking when under a condition of friction. The common procedure here uses a sample of conveyor belting tensioned around a drum that rotates at a specified speed. (**Figure 15.8.**) This simulates a stalled belt where a drive pulley continues to rotate, or a stalled idler when the belt passes over it. This is often called the Drum Friction Test.

In this procedure, a test piece of conveyor belt, suitably mounted and tensioned, is wrapped half way around a rotating steel drum simulating a stalled belt. The test is continued at specified tensions for a given time period or until the belt breaks. The presence, or absence, of flame or glow is noted and the temperature of the drive drum is measured. The test may be conducted in still air and/or in moving air.

In most standards, the belt or the belt debris emitted from the drum rotation must not catch fire during a specified test duration. The sample may break or remain intact depending upon the test standard. The maximum temperature the drum reaches during the test is also specified.

For coal mine applications, the maximum drum temperature allowed is often specified as 325°C [≈617°F] which is below the ignition temperature of coal dust. Some standards allow drum temperatures up to 400°C [≈752°F] for nonflammable cargos.

The basic test methods are published most recently in *BS EN 1554:2012*. Requirements differ in various European countries.

Testing for Resistance to Ignition

Resistance to ignition is probably the simplest test to perform and provides a basic test for manufacturing quality control while also ensuring a predetermined level of resistance to ignition of the conveyor belting. It provides a measure of the possibility of igniting the considerable mass of a conveyor belt with a relatively small ignition source.

In most tests, a sample of conveyor belting one-half inch to one inch [≈12 to 25 mm] wide is subjected to a laboratory Bunsen burner for a period between 30 and 60 seconds. (**Figure 15.9.**) The burning sample may or may not be subjected to a known airflow during or after the test. When the burner's flame is removed, the time required for the belt sample to self-extinguish is measured. A specified number of samples are tested and the average time for extinguishing is calculated. The upper limit for this average is specified in most of the standards worldwide.

Around the world, there are many differences in sample characteristics, burner location, and air flow during and after testing making it difficult to directly compare standards from country to country.

In Europe and much of the rest of the world, the *EN/ISO 340* test involves exposing six individual samples of a belt to a naked flame. Some countries test with and without cov-

2

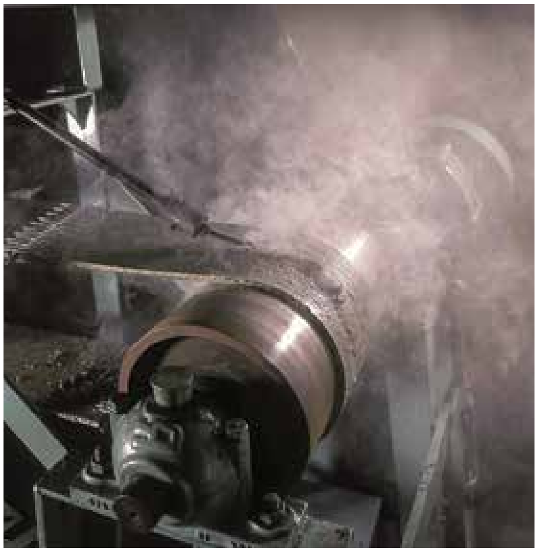


Figure 15.8.

Drum friction test.

Photo courtesy of Fenner Dunlop.

ers, other countries test only with covers on. The specification calls for each sample to be suspended in a vertical plane with the burner set at a 45-degree angle. The source of the flame is then removed, and the combustion time (duration of the flames) of the test piece is recorded. A current of air is then applied to the test piece for a specified time after the removal of the burner; the flame should not reignite. The time it takes for the belt sample to self-extinguish is measured. The duration of continued burning (visible flame) is then measured; it should be less than 15 seconds for each sample with a cumulative duration of 45 seconds maximum for each group of six tests. This duration factor is of paramount importance because it represents how long a fire can be carried along a moving belt.

Figure 15.9.

Bunsen burner-style resistance to ignition testing procedure.

Photo courtesy of Fenner Dunlop.

Figure 15.10.

Arrangement for full-scale gallery fire propagation testing.

Photo courtesy of Fenner Dunlop.

Figure 15.11.

Full-scale gallery fire propagation test underway.

Photo courtesy of Fenner Dunlop.

Testing of Fire Propagation

The Propagation of Fire Test may be the most important requirement for conveyor belting, and over the years a number of large-scale testing protocols have been adopted around the world. These procedures are usually referred to as Gallery Fire Tests. (**Figure 15.10.**)

Historically, these have been large-scale tests that involved the use of significant amounts of belting and fuel to ignite the sample belt. The normal method of testing is to measure the length of belting left undamaged after subjecting the sample to a fire for a fixed duration and fuel consumption. The heat input is sometimes also measured.

These full-scale tests have included test samples at full belting widths, with lengths specified between 2 and 50 meters [≈6 and 164 ft]. Idler sets are sometimes used to support the belt; supplemental fuels range from wood and shavings to propane and gasoline.

According to the Fenner Dunlop 2013 white paper, *MSHA B.E.L.T. or not MSHA B.E.L.T.…that is the question?*, the test procedure (**Figure 15.11.**) was originally part of the United Kingdom, Australian, and German Institute for Normalization (DIN) standards. In these procedures, a two-meter-long sample of conveyor belting of a standard width is supported on a trestle simulating the idler configurations. The sample was ignited for 10 minutes using a propane burner—consuming 1.3 kilograms [≈2.9 lb] of fuel—under a standard air flow. After the ignition source has been removed, the flames must self-extinguish and a defined undamaged length of belting must remain. To meet the standard, 250 millimeters [≈10 in.] of belting must be left undamaged at the end of the test when all flames are extinguished. The standard *DIN EN 12881-2: 2009* included simulated damage to the belting sample to expose its fabric reinforcement.

While this testing method is effective and repeatable, the test itself required large-scale facilities and created environmental, health, and safety issues.

Mid-Scale Propagation Testing

The current trend in fire propagation testing is to use much smaller samples in a laboratory-sized testing device. (**Figure 15.12.**) Referred to as mid-scale tests, these procedures are designed to achieve the same results as full-scale testing while needing smaller facilities and reduced expenditures. The mid-scale or 'laboratory-scale' tests are less expensive to carry out, and by reducing smoke emissions curtail the environmental impact of the test.

For example, in the United States, the MSHA Belt Evaluation Laboratory Test (B.E.L.T.) requires the ignition of a 9 inch by 60 inch [≈229 mm by 1,524 mm] sample of belting for five minutes using a methane burner. (**Figure 15.13.**) Gas flow is adjusted to 1.2 cubic feet per minute [≈34 l/min], as noted in the paper, *Flammability of wider conveyor belts using large-scale fire tests* by J.H. Rowland III and A.C. Smith. The sample is held on a support stand of specified dimensions and three tests are carried out. All the samples must leave a measurable length of belting undamaged after the test. (**Figure 15.14.**)

The European approach has been to utilize the same cabinet as the full-scale tests, but with modifications to the burner and test conditions to provide pass/fail results similar to the larger tests.

As specified by Bernd Küsel in his PowerPoint presentation titled *International Comparison of Fire Resistant Conveyor Belts*, in the Laboratory Scale Gallery Test *DIN 22100* and *22118*, a belting sample 1,200 millimeters long by 120 millimeters wide [≈47.2 in. long by 4.72 in. wide] is placed over a propane burner. (**Figure 15.15.**) Similar to the B.E.L.T. standard, after the ignition source has been removed, the flames must self-extinguish and a defined length of undamaged belt must remain.

South Africa and Canada have recently adopted standards similar to the European DIN testing.

Figure 15.12.

Laboratory-scale flame test equipment as used for the B.E.L.T. test procedure.

Photo courtesy of Fenner Dunlop.

Figure 15.13.

B.E.L.T. testing procedure.

Photo courtesy of Fenner Dunlop.

2

Limiting Oxygen Index Testing

One final test seen in conjunction with conveyor belting fire-retardance standards is the Limiting Oxygen Index Test, or LOI. This test is used to establish if a particular piece of belt is in fact identical to a sample that was tested and approved earlier. It provides an inexpensive and efficient way to check whether the belting supplied is in accordance with the agreed fire-safety requirement.

The Limiting Oxygen Index represents the minimum concentration, expressed as a percentage, of oxygen to maintain steady burning. It is measured by passing a mixture of oxygen and nitrogen over a burning specimen, and then reducing the oxygen content in the mixture until reaching a critical level where combustion is not sustained.

Fresh air contains about 21 percent oxygen. A polymer with an oxygen index lower than this will burn freely in air; one with an oxygen index that is higher will extinguish itself unless a flame is applied to it. Thus a high oxygen index means higher resistance to self-sustained burning. The typical LOI test checks to see if the sample will support combustion for longer than 180 seconds after ignition.

Figure 15.14.

To pass the B.E.L.T. test, an unburned portion of the belting sample must remain after the test procedure.

Photo courtesy of Fenner Dunlop.

Figure 15.15.

European mid-scale gallery testing.

Photo courtesy of Fenner Dunlop.

LOI is not a test of flame retardance in itself, but rather is applied as a quality control method. The result from a tested sample must conform to the results of a previously approved belt of the same type.

LOI values for different materials are determined by standardized tests, such as the *ISO 4589* in Europe and *ASTM D2863* in the United States. In Europe *DIN 22117* specifies the LOI for conveyor belts used in coal mines.

According to Küsel's PowerPoint, *ISO 4589* specifies a 150 by 50 millimeters [≈6 x 2 in.] specimen of belting be positioned vertically in a transparent test column and the oxygen and nitrogen mixture is forced upward through the column. The specimen is ignited at the top and the initiating flame is removed. The oxygen concentration is then adjusted until the specimen just supports combustion.

Smoke Density and Toxicity

In addition to the hazards of the fire itself, there must be concerns with the density and toxicity of smoke emitted from burning belting. A complicating factor is that increasing the amount of fire retardant in the belting can, in turn, lead to more dangerous smoke.

In 1995, Joseph Main, then Administrator of the Department of Occupational Health and Safety of the United Mine Workers of America labor union, commented on the dangers of the toxic smoke. Main, who later became United States Assistant Secretary of Labor for Mine Safety and Health, and consequently head of MSHA, wrote:

> Another serious concern is the black, billowing smoke produced when conveyor belts burn. This heavy smoke has hindered the escape of miners due to visual obscurity and respiratory contamination. *R.I. [Report of Investigation] 9380* also supports this contention, stating in part, 'In addition, the levels of smoke and CO [carbon monoxide] produced begin to approach dangerous

> levels and lethal levels may subsequently result during the propagation stage.'

A number of countries including Germany, Poland, and the Czech Republic have belt-testing standards covering smoke emissions.

At present, there are no regulations in the United States. On June 19, 2008, MSHA released a Request for Information (RFI 1219-AB59 and/or RFI 1219-AB60) on conveyor belt combustion toxicity and smoke density (73 FR 35057). The responses to this request for information discussed many of the issues regarding smoke from a burning belt.

The response to the Request for Information from the Center for Regulatory Effectiveness cited a February 5, 1996, letter to MSHA from representatives of the chemical supplier Monsanto:

> It is not uncommon for flame retardants to actually increase the amount of smoke produced per unit of material burned. … The net effect of this is often NOT the desired reduction in smoke … sometimes the total smoke generated goes up!
>
> … (The) total smoke generated could be greater because of the much higher production of smoke per unit of mass consumed.

This Monsanto letter also noted the lethality of a burning belt "is greatly enhanced by smoke opacity which obscures all visual clues and prevents victims from escaping the threatened area."

The health issues with smoke from belting include:

- Carbon monoxide
- Toxic gases such as hydrogen cyanide (HCN) and sulfur dioxide (SO_2)
- Irritants such as smoke particulates
- Convective and radiant heat
- Oxygen depletion

In his presentation to the Belt Air Panel, Bernd Küsel of Germany's Phoenix Conveyor Belt Systems stated, "By far the major threat during a fire, aside from heat, is carbon monoxide – an odorless gas." He then pointed out that all common conveyor belt bases—polychloroprene rubber (CR) and styrene butadiene rubber (SBR), both elastomers; and polyvinylchloride (PVC), categorized as a plastomer or thermoplastic—develop roughly the same amount of carbon monoxide.

The toxicity of smoke from a belt fire does not seem to be a concern, at present, for regulators or safety professionals. In his presentation to the Belt Air Panel, C. David Litton, a physicist from the United States National Institute for Occupational Safety and Health (NIOSH), noted that smoke from a fire causes a visibility hazard well before a toxicity hazard develops.

In his response to the MSHA Request for Information RIN 1219-AB59, Marcelo Hirschler summarized this point:

> … Although roughly two-thirds of fire victims die from the effects of smoke inhalation, it is extremely rare for the root cause of their deaths to be that the smoke comes from a specific very toxic material. Fire fatalities are usually the result of inhaling too much smoke of average toxicity.

The issue, it seems, is the amount of smoke, not its toxicity.

REGULATIONS AND STANDARDS

A general overview of what various countries require in belt testing is shown in **Figure 15.16**.

The array of testing procedures, national standards, and regulatory bodies has created difficulties to know what complies and what is safe. The research report, *Fire safety testing of conveyor belts*, published by the United Kingdom's Health and Safety Executive, noted that as of 2002,

> Four different types of conveyor belt fire propagation tests are currently specified in the European Union for the acceptance testing of belts for use in coal mines. The tests vary in length of belt sample, type, intensity and duration of heat source and test gallery geometry. A comparison exercise carried out under the auspices of the ECSC [European Coal and Steel Community] in the early 1990's and followed up later in the UK revealed that belts which met the acceptance requirements in some of the tests failed others, and some belts which performed well in certain tests burned out completely in others.

It summarized:

> There was therefore a variation in the stringency of the acceptance criteria and an indication that the tests were not necessarily measuring the same properties.

There are different standards and tests required for conveyor belts in various countries. These standards are identified in **Figure 15.17**, and detailed in the following section.

Australia

Australian standard *AS 4606-2000 Fire resistant and antistatic requirements for conveyor belting used in underground coal mines* has been superseded by *AS 4606-2012 Grade S fire resistant and antistatic requirements for conveyor belting and conveyor accessories.*

Methods for testing conveyor belt fire resistance are included under the *AS 1334* standard, including:

> *1334.9-1982*
> *Methods of testing conveyor and elevator belting – Determination of electrical resistance of conveyor belting*

Figure 15.16.

Belt flammability requirements in countries around the world.

Test	China	USA	India	Australia	Europe	South Africa	Russia
Drum Friction	Yes	No	Yes	Yes	Yes	Yes	Yes
Propane Grate Burner	Yes	No	Yes	Yes	Yes	No	Yes
High-Energy Propane Burner	Yes	No	No	No	Yes	No	No
Large-Scale Gallery	No	No	No	No	Yes	No	No
Laboratory-Scale Gallery	No	Yes	No	No	Yes	No	Yes
Bunsen/Spirit Burner	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Surface Resistance	Yes	No	Yes	Yes	Yes	Yes	Yes
Toxicity	No	No	No	No	Yes	No	Yes
Oxygen Index	No	No	No	Yes	Yes	No	Yes

Figure 15.17.

Conveyor belt fire resistance standards around the world.

COUNTRY	STANDARD
Australia	*AS 4606*
Belarus	*MI 600024712.001-2007*
Canada	*CSA M422-M14*
China	*MT914*
Czech Republic	*CS EN 14973 C1*
Germany	*DIN EN 14973 C2*
India	*IS3181*
Italy	*UNI EN 14973 C1*
Norway	*NS EN 14973C1*

COUNTRY	STANDARD
Poland	*PN EN 14973 C1 + PN-93-05013*
Portugal	*IPQ EN 14973 C1*
Russia	*PD03-423-01*
South Africa	*SABS 971*
Spain	*UNE EN 14973 C1*
Turkey	*TS EN 14973 C1*
UK	*BS EN 14973 C1*
Ukraine	*GTSU 12.0018579.001-99*
USA	*MSHA Title 30 Part 14 & MSHA 2G*

1334.10-1994
Methods of testing of conveyor and elevator beltings – Determination of ignitability and flame propagation characteristics of conveyor belting

1334.11-1988
Methods of testing conveyor and elevator belting – Determination of ignitability and maximum surface temperature of belting subjected to friction

1334.12-1996
Methods of testing conveyor belting – Determination of combustion propagation characteristics of conveyor belting

Canada

Canada's reliance on regulatory inspections and code enforcement at the province levels make compliance a little more confusing than relying on standards issued at the national level. But in general, the programs and requirements are relatively uniform, with the requirements conforming to standards developed by the Canadian Standards Association (CAN/CSA).

Part 4.4.16 of the *Health, Safety and Reclamation Code for Mines in British Columbia* (published in 2008) specifies:

> 12) Conveyor belting for use in the transportation of coal or in an explosive atmosphere and in all underground locations shall meet the requirements of CSA standard *CAN/CSA-M422-M87 Fire Performance and Antistatic Requirements for Conveyor Belting* or an equivalent standard subject to approval by the chief inspector.

CSA M422-M87 (issued in 1987) has now been superseded, first by *CSA M422-12*, issued in 2012, and more recently with the 2014 publication of *CSA M422-14*.

For many years, belting used in Canada had to comply with the fire-retardance standards established by MSHA in the United States. However, as of March 20, 2013, Carleton University eliminated the need to rely on non-Canadian standards and testing through the development of a testing facility which made a Canadian certification available.

The *CAN/CSA M422-14* standard specifies fire-performance and antistatic requirements for new (unused) conveyor belting for use in any part of a mining or excavation operation that is below the surface. This standard covers fire-performance and antistatic conveyor belting of the following types:

a. Types A1 and A2, intended for use in explosive atmospheres.
b. Types B1-A, B1-B, B2, and C, intended for use in non-explosive atmospheres.

China

Standards for fire-retardant belting in China are identified in several standards:

MT 668: 2008 Steel cord fire resistant conveyor belting for coal mine

MT 914: 2008 Solid woven fire resistant conveyor belting for coal mine

Both standards are intended for underground coal mines, and include information on the specifications, technical requirements, test methods, inspection rules, signs, packaging, transport, and storage of the identified belting.

Europe

Standards in Europe, and other regions governed by the *EN ISO Safety Standards*, are issued by the European Committee for Standardization (called CEN, from the French Comité Européen de Normalisation). They include:

Electrical and Flammability Safety Requirements

EN 12882:2008 General Purpose Belting

EN 14973:2006 + A12008 Underground Belting

General Purpose Belting Standards

EN ISO 14890:2013 Textile Belts

EN ISO 15236-1:2005 Steel Cord Belts

Underground Belting Standards

EN ISO 22721:2007 Textile Belts

EN ISO 15236-3:2007 Steel Cord Belts

EN 12882 is the standard for safety requirements of conveyor belt for general aboveground purposes. This standard divides belting into five safety categories, according to the given belt's performance under the various types of testing. (**Figure 15.18.**)

As noted in the European Commission report, *Early detection and fighting of fires in belt conveyor (Edaffic), DIN EN 14973* defines the safety requirements for electricity and fire protection on conveyor belts used in underground mining in the presence of flammable and nonflammable atmospheres.

2

Additionally, it lists the following aditional hazards for the use of conveyor belts in underground mining, including:

- Risks due to emissions of static electricity;
- Risks caused by the standstill of the conveyor belt while the drive is still running which leads to a local heating of the conveyor belt and which may cause frictional heat due to the contact with the motor drum or other parts causing frictional heat;
- Risks regarding the impact of small open flames on the cover or the casing of the conveyor belt can have;
- Risks caused by fire spreading along a conveyor belt. Such a fire may be caused by a rather small hot spot; for example, the overheated bearing of a pulley, or by larger fires caused by other materials inside the gallery.

This underground belting standard establishes a set of three classes with two of the classes each divided into two subdivisions. (**Figure 15.19.**)

The test methodologies for conveyor belts in Europe are spelled out in the following standards, although there may be differences in testing method and/or the performance required to pass in various regions.

DIN EN ISO 284:2012
Conveyor belts – Electrical conductivity – Specification and test method.

DIN EN 1554:2012
Conveyor belts – Drum friction testing.

BS EN 12881-1:2014
Conveyor belts. Fire simulation flammability testing. Propane burner tests.

EN 12881-1 describes four methods for measuring the propagation of a flame along a conveyor belt which has been exposed to a relatively high localized heat source such as a fire. The damage suffered by the conveyor belt, as well as its tendency to support combustion, is measured by observing the extent to which the fire spreads along the test piece.

Method A uses a test piece 2 m [≈6.56 ft] in length and consumes propane gas through the burner at the rate of 1.30 ± 0.05 kg per 10 min [≈0.286 lb_m/min].

Figure 15.18.

Summary of categories and requirements in BS EN 12882-2002.

Summary of Safety Classes in *BS EN 12882:2001*

Category	Electricity Resistance Requirements	Ignition Requirements	Drum Friction Requirements	Fire Propagation Requirements
1	*			
2	*	*		
3	*	*	*	
4	*			*
5	*	*	*	*

Method B uses a test piece 2.5 m [≈8.2 ft] in length and consumes propane gas through two burners mounted above and below the test piece trestle at the rate of 1.30 ± 0.05 kg per 10 min [≈0.286 lb_m/min] for each burner.

Method C uses a test piece 1.5 m [≈4.9 ft] in length and consumes propane gas through the burner at the rate of 565 ± 10 g per 50 min [≈0.025 lb_m/min].

Method D uses a test piece 1.2 m [≈3.9 ft] in length and consumes propane gas through the burner at the rate of 150 l/hr. [≈5.3 ft^3/hr](D1) or 190 l/hr. [≈6.7 ft^3/hr]((D2).

DIN EN 12881-2:2009
Conveyor belts. Fire simulation flammability testing. Large scale fire test.

This test simulates a situation in which sources of fuel are present in addition to the source of ignition on the conveyor belt and these may be ignited too. This simulation is done by starting a fire load of wood, as described in the *Early detection and fight of fires in belt conveyors* (Edaffic).

BS EN ISO 340:2013
Conveyor belts. Laboratory scale flammability characteristics. Requirements and test method

This standard specifies a method for assessing, on a small scale, the reaction of a conveyor belt to an ignition flame source. It is applicable to conveyor belts having a textile carcass as well as steel-cord conveyor belts.

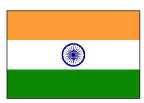
DIN 22117 (1988-02)
Conveyor Belts for Coalmining – Determination of the Oxygen Index

DIN EN ISO 4589-1:1996
Plastics – Determination of burning behaviour by oxygen index – Part 1: Guidance

DIN EN ISO 4589-2(2006-06)
Plastics – Determination of burning behaviour by oxygen index – Part 2: Ambient-temperature test

DIN EN ISO 4589-3:1996
Plastics – Determination of burning behaviour of plastics by oxygen index – Part 3: Elevated-temperature test

In addition, belting should comply with the requirements of the *ATEX Directive 2014 /34 EU* which covers equipment and protective systems intended for use in potentially explosive atmospheres.



India

In India, standards for fire retardance in conveyor belting are covered in standard *IS 1891-5 (1993) Conveyor and elevator textile belting*: Part 5: Fire resistant belting for surface application.

That standard contains the following subsections which describe the approved test procedures:

- Annex A (Clause 9.1) Method of Test for Fire Resistance (Drum Friction Test)

Summary of Safety Classes in *BS EN 14973:2006*

- Class A, general use, the only hazard being limited access & means of escape
- Class B, as above plus a potentially explosive atmosphere
  - B1 – no secondary safety devices
  - B2 – with secondary safety devices
- Class C, as Class B plus flammable dust or material conveyed
  - C1 – no secondary safety devices
  - C2 – with secondary safety devices

Figure 15.19.

Summary of Safety Classes in BS EN 14973:2006.

- Annex B (Clause 9.2) Method of Test for Fire Resistance (Flame Test)
- Annex C (Clause 9.3) Method of Test for Electrical Surface Resistance

Belting for underground use is covered in standard *IS 3181 (1992): Conveyor belts – Fire resistant conveyor belting for underground mines and such other hazardous applications,* which includes the following test procedures:

Annex E (Clause 14) Method of Test for Electrical Resistance

Annex F (Clause 15.1) Method of Test for Fire Resistance (Drum Friction Test)

Annex G (Clause 15.2) Method of Test for Fire Resistance (Spirit Burner Flame Test)

Annex H (Clause 15.3) Propane Burner Test

South Africa

The South African standards for the testing of the fire-retardant properties for belting are spelled out in *SANS 971*; the current edition was published in 2013.

SANS 971 details the test methods for fire-retardant properties for belting of all types of construction. The actual compliance requirements are specified in the other applicable standards, including:

- *SANS 1366:2006 Steel Cord Reinforced Conveyor Belting*
- *SANS 1173:2006 General Purpose Textile-Reinforced Conveyor Belting*
- *SANS 968:2013 Conveyor Belting –Textile Reinforced Solid Woven Conveyor Belting*

SANS 971:2013 uses the same methods of testing for all constructions of conveyor belting. Compared to the previous versions, the 2013 edition spells out the use of an existing drum friction test, electrical resistance test, and flame 'initiation' test with minor changes, and adds a mid-scale fire-propagation test.

Within *SANS 971*, the standards specifying methods of testing include:

6.1 Conditioning

6.2 Flame resistance

6.3 Electrical conductivity

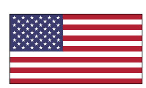
6.4 Drum friction test

6.5 Flame propagation test

This standard specifies methods of testing fire-retardant conveyor belting, including belting to be used in what are termed 'fiery mines.' A fiery mine is defined as a mine in which a) the workings give off an amount of flammable gas, b) there is a danger of explosion due to dust or flammable gas, or c) gas ignitions and outbursts have occurred in the past.

In addition, *SANS 971* cites the following documents as 'indispensable' for its application:

- *EN 12881-1, Conveyor belts – Fire simulation flammability testing – Part 1: Propane burner tests.*
- *SANS 340/ISO 340, Conveyor belts – Laboratory scale flammability characteristics – Requirements and test method.*
- *SANS 10284/ISO 284, Conveyor belts – Electrical conductivity – Specification and test method.*
- *SANS 23529/ISO 23529, Rubber – General procedures for preparing and conditioning test pieces for physical test methods.*



United States

For many years, the United States trailed the rest of the standardized world in its adoption of standards for testing and performance for fire-retardant belting. The Belt Air Panel report noted:

> It is obvious from the comparison that the requirements for belt fire resistance in the United States are among the lowest in the world with only a small-scale Bunsen burner laboratory test required.
>
> All other countries require a drum friction test and most countries also require

> a larger-scale propane grate burner test. A large-scale gallery test is only required in Europe but a laboratory-scale gallery test is required in both Europe and Russia.

But the fatalities in the Aracoma Alma Mine in West Virginia in January 2006 brought a renewed focus to conveyor belt-related fires and the risks they create for miners' safety. This tragedy spurred regulators to investigate, propose, and accept more rigorous standards and testing procedures.

The conveyor belting in the Aracoma Alma fire was determined by post-fire testing to meet the United States' then current MSHA laboratory fire-test standard as expressed in *Title 30 CFR 18.65* (generally known as Schedule 2G). (**See The Aracoma Mine Fire: Frictional Heat Leads to Tragedy.**) However, that belting did not meet the standards of the *Belt Evaluation Laboratory Test* (commonly called B.E.L.T. or BELT), which had been developed in the late 1980s by MSHA but never implemented. MSHA had proposed the B.E.L.T. Standard in 1992 but withdrew it 10 years later saying the number of fires had decreased.

In the Mine Improvement and New Emergency Response (MINER) Act of 2006, the United States Secretary of Labor established the Technical Study Panel on the Utilization of Belt Air and the Composition and Fire Retardant Properties of Belt Materials in Underground Coal Mining (usually referred to as the Belt Air Panel). This panel conducted an independent scientific and engineering review and made recommendations on topics including flame-retardant properties of belt materials for use in underground coal mines. The Belt Air Panel issued its final report on December 20, 2007.

In studying the Aracoma tragedy, the Belt Air Panel noted the weakness—or lack—of United States standards. In Recommendation 3 in its final report, the panel noted:

> It is obvious ... that current U.S. conveyor belt flame-resistance testing and standards are inadequate to correctly determine the full-scale fire resistance of conveyor belt ...

As a consequence of this report, the B.E.L.T. standard was adopted, bringing the United States more into standardization with practices elsewhere around the world. This new standard, now contained within Part 14, has been in place since December 31, 2008.

The NIBA Technical Article, *Conveyor Belt – New MSHA standard*, by Mitesh Kadakia, notes that belting for underground coal mine use must meet the performance requirements of the B.E.L.T. laboratory propagation test. The key difference in performance between the old and new standards is that the old Schedule 2G standard required the belt to be only ignition-resistant. A simple laboratory Bunsen burner test was engaged to assess the performance against standard criteria. The new Part 14 standard also requires the belt be resistant to fire propagation down the length of the belting sample when subjected to fire/fuel from an external source.

The B.E.L.T. was developed by the United States Bureau of Mines (with cooperation from MSHA) to address the limitation of the Schedule 2G test by providing a sample size and test conditions that lead to results that align more closely with those of the full-scale gallery test. The test is conducted in a relatively simple laboratory setting that does not require a full-scale belt-fire gallery.

Details of the procedure were summarized by Marcelo M. Hirschler of GBH International in a response to the Belt Air panel's *Request for Information RIN1219-AB59*:

> The BELT test … is conducted in a 1.7 m (5.5 ft) long by 0.2 m^2 (1.5 ft^2) ventilated tunnel. The belt material sample size is 1.5 m (5 ft) long by 230 mm (9 in.) wide. The sample is ignited by applying a gas burner to the front edge of the belt sample with the flames distributed equally on the top and bottom surfaces of the sample. After five minutes, the burner is removed, and

2

the belt sample allowed to burn until the flames are out. A belt passes the BELT if, in three separate trials, there remains a portion of the conveyor mine belt sample that is undamaged across its entire width. If in any of the three trials, fire damage extends to the end of the sample, the conveyor belt formulation fails the test.

Because frictional heating is a common cause of belt fires, the Belt Air Panel recommended that MSHA evaluate a drum friction test. However, after evaluation, MSHA decided not to proceed with adding that test as a requirement.

To comply with the requirements in *30 CFR 14*, as of December 31, 2009, all new belts in underground coal mines need to have a higher flame resistance. After another 10 years, all belts supplied prior to 2009 will have to have been replaced with compliant belting.

For non-coal activities in underground mines, as well as conveyor applications above ground, the old standard Part 18 belting may still provide the end user with a level of fire performance deemed acceptable. This should be determined with a risk-assessment study of the environment where the belt will be operating.

According to a white paper *MSHA B.E.L.T. or not MSHA B.E.L.T.…that is the question?* from Fenner Dunlop, the Association for Rubber Products Manufacturers (ARPM) created two classes for fire retardance that could be specified in a belting order:

ARPM – FR Class 1
This class incorporates the new MSHA standard *30 FFR Part 14* from December 2008. The test method is also contained in *ASTM D378 Part 13.1*, and is also known as the B.E.L.T. test.

ARPM – FR Class 11
This class of conveyor belting is based on the previous MSHA specification in use for underground coal mines known as Schedule 2G or *CFR 30 Part 18* belts. The test method is specified in *ASTM D378* Part 13.2., and employs 6 inches x 0.5 inch (≈152 mm x 13 mm) sized belt test samples. In accordance with the original MSHA guidelines, the acceptance criteria for belt samples tested to this standard is defined as the tests of four specimens cut from any belt sample shall not result in either duration of flame exceeding an average of one minute after removal of the applied flame, or the continuation of visible glowing of a specimen after flaming has ceased (afterglow) exceeding an average of three minutes duration.

The Need for Global Standards

The discussion in this chapter cites an almost incomprehensible list of standards, tests, and requirements for fire and static specifications for belting. The variations and contradictions between, and often within, countries significantly increase the risk of misapplying belting and components.

The number of fatalities from belt fires indicates what the standards require is not yet adequate. For example, components such as belt cleaners and skirt seals should pass not only the fire-propagation tests but a type of drum friction test. Components in contact with the belt are often over-adjusted by maintenance people in order to keep the belt running, albeit unsafely, rather than treating the root cause and making the operation safer. The worldwide complexity and differences in the safety standards and testing procedures increase rather than reduce risk. Global safety standards for bulk-materials-handling belts are long overdue.

As bulk-materials handling has become a global industry, governments and standards-issuing organizations could contribute greatly to conveyor belt fire safety by agreeing upon a single global set of standards for conveyor belt-fire mitigation.

Determining the Appropriate Level of Fire Retardance

As Sytze Brouwers notes in “Playing with fire?” in the January 2014 edition of *Dry Cargo International*, many sites that should be using fire-retardant belting are operating with non-fire-retardant belts simply because of ‘economy’—the desire to save money.

Conveyor belts cannot be made totally fireproof. Top and bottom covers and the rubber skim between the plies can be engineered to retard fire, but the complete structure of the belt cannot be fireproof. Some manufacturers supply certificates that may only relate to the belting that the manufacturer produced for general certification, rather than to the specific belting supplied for the specific applications. Consequently, one manufacturer recommends that an additional meter of belting be ordered, so that this extra length can be tested by an accredited laboratory to verify compliance with certification requirements.

Of course, it is imperative that conveyor belts used in the mining and handling of coal, as well as any other underground applications, comply with legal requirements for fire retardance. Outside of those instances, a risk evaluation can help determine the level of fire retardance appropriate for a given belting application.

Whenever a conveyor belt is running inside or between buildings or is in a confined space, it is a good plan to specify a higher level of fire retardance.

In above-ground (non-regulated) applications, additional fire-suppression systems are helpful, and when installed may allow the user to consider a lower fire standard for the conveyor belting. However, the danger of relying on secondary devices—fire sensing and deluge systems, for examples—is related to the maintenance of these systems. When a high fire-retardancy conveyor belt is specified, it becomes somewhat of an insurance policy to mitigate damages.

Whenever there is doubt on the severity or cost penalty of a hazard, it is a very good strategy to upgrade the operating safety level. Thus it is a good practice to include fire-retardant belting in applications where the cost of a fire would be significant or mission critical.

Beyond Belting: Fire Retardance of Other Conveyor Components

On conveyors there are a number of other components that commonly or occasionally come into contact with the moving belt. As a result, they should be evaluated for their propensity to burn and/or create friction that may cause the belt to catch fire. Most commonly, the requirements covering these materials are issued in the regulations covering underground mining and/or coal mining, as these operations can present the greatest risks.

Elastomer and rubber components such as pulley lagging, skirt seals, the blades on belt cleaners and tail pulley plows, and the elastomer bars used in belt support slider beds and impact cradles should comply with the regulatory standards for fire retardance. Even the grease used in lubricating conveyor idlers should be fire-retardant. Any component or assembly that comes into contact with the moving belt, whether it has the potential to generate friction by sliding or rotating, should be rated at least as fire-retardant as the belt.

In some jurisdictions (notably Australia, Canada, and the United Kingdom), light alloys—those in which the total weight of aluminum, magnesium, and titanium together exceeds 15 percent, and/or in which the content of magnesium and titanium together exceeds 6 percent, by weight—are prohibited in underground coal mines. This restriction is intended to limit the hazard of light metal alloys becoming a source of ignition of gas or dust. Friction or sparking resulting from light metals striking or being struck by oxidized (rusty) ferrous metal is enough to ignite a mixture of methane and air.

Other fire-control practices require the use of fire-resistant (nonflammable) hydraulic fluid and other chemicals.

In the USA

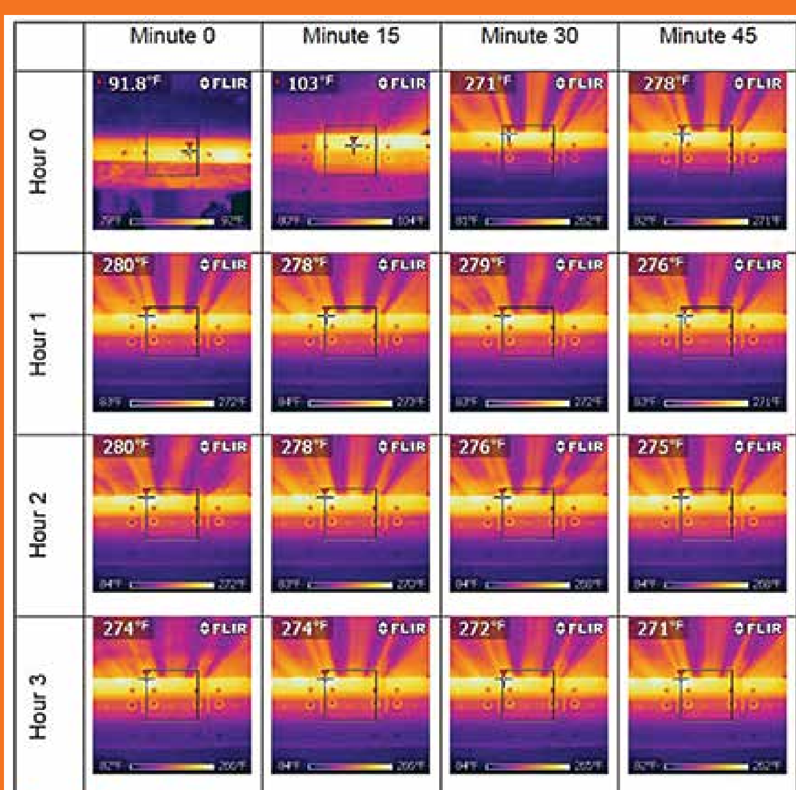
In the United States, MSHA has procedures in place to accept various elastomer components for use underground. These include conveyor components such as chute liners, pulley lagging and idler roll covers, impact bars, belt wipers, and belt skirt rubber, as well as other elastomer components, such as air and hydraulic hoses and seat cushion material.

The *Code of Federal Regulations (CFR), Title 30* contains mandatory regulations for flame-resistant requirements of many products used in underground mines. However, there are numerous other products which may present similar fire hazards, but for which no specified test and/or regulation exist. As a result, this procedure provides for the testing and evaluation of these materials.

The procedures are spelled out in MSHA's *Document No. ASAP 5001 Application Procedures for Acceptance of Flame-Resistant Solid Products Taken Into Mines*.

The acceptance procedure requires submission of formulation information, (material) safety data sheets (SDS), and a number of samples—usually four specimens from a given lot—to be tested. The test procedure is detailed in *MSHA Document ASTP 5007 MSHA's Standard Flame Test Procedure for: Hose Conduit, Fire Suppression Hose Cover, Fire Hose Liner and Other Materials; Title 30, Code of Federal Regulations Part 18,* section 18.65. This document spells out the sample characteristics and the equipment and procedure used for the testing; the testing protocol is identical to the Schedule 2G procedure formerly used for the evaluation of conveyor belting.

Can Belt Cleaner Blades Start a Belt Fire?



Thermal images of the cleaning edges.

The question of whether belt-cleaner blades get hot enough from belt friction to start a fire is a consideration for operations employing high-speed conveyors.

Belt-cleaner blades are tensioned against a moving conveyor belt to remove carryback, the residual material that sticks to the belt past the discharge point. The blade-to-belt contact pressure creates frictional heat. Sometimes the blade-to-belt pressure is elevated; sometimes multiple cleaners are installed; sometimes the cargo is abrasive and/or flammable. All increase the concern for fire.

To determine if there is a real risk of cleaning blades causing a fire, researchers at Martin Engineering's Center for Innovation conducted a series of tests. The testing would ascertain if the metal blades in contact with the belt ever reached a typical belt's flammability temperature of 300°C [≈572°F].

Upon successful testing and evaluation of the submitted product sample, MSHA will issue an acceptance number. The product shall be permanently and legibly labeled with this acceptance designation. A product may be advertised as 'accepted by MSHA' but terms such as 'approved,' 'recommended,' or 'sanctioned' by MSHA must not be used.

Other Countries

For Australia, the *AS/NZS 4024.3610* standard specifies in section 3.2.6.1 that non-metallic materials used in conveyor components are required to match the fire-resistance requirements specified in *AS 4606 for Grade S fire resistant and antistatic requirements for conveyor belting and conveyor accessories*. Components specifically identified include chutes and lining, hoods and covers, and other items in contact with the belt, such as lagging, impact bars, skirt-sealing strips, and belt cleaner blades.

A variety of other national and international standards organizations are responsible for preparing and issuing standards relating to elastomers. These include the International Organization for Standardization (ISO), the British Standards Institution (BSI), the American Society for Testing and Materials (ASTM), the Deutsches Institut für Normung (DIN), the European Association of Aerospace Industries (AECMA), and the Association Français de Normalisation (AFNOR).

Care should be taken to see that other conveyor components—and specifically those incorporating elastomer—have been evaluated properly for fire-resistance performance before their application.

Buyer Beware

Some elastomers and components are identified as fire-retardant (or fire-resistant) and antistatic—often FRAS or FR/AS—in their

Testing Tungsten Carbide Blades

In the test procedure, a secondary belt cleaner with tungsten carbide-tipped blades was tensioned against a dry (and empty) belt moving at 4 meters per second [≈787 fpm]. The cleaner and belt were both 457 millimeters [≈18 in.] wide. Every 15 minutes the temperature of the blades was recorded by taking a thermal photograph of the cleaning edge.

During the test, the hottest the tungsten carbide cleaning edge reached was 138°C [≈280°F]—a temperature that is approximately one half the ignition temperature for the belting. This temperature was recorded at the beginning of Hours 1 and 2 of the testing. After the first 30 minutes of the test, the temperature of belt and cleaner stabilized and consistently showed temperatures between 133°C [≈271°F] and 138°C [≈280°F]. After four hours, the procedure was discontinued.

In an expanded test where a cleaner was significantly over-tensioned (to as much as 200 percent of optimal blade-to-belt pressure), the maximum temperature remained under 138°C [≈280°F]. These results show that friction from blade-to-belt contact would not heat a cleaner blade enough to cause a belt fire.

Urethane Blade Testing Too

Martin Engineering's German facility conducted similar testing to check the temperatures reached by a urethane belt cleaner blade. The German tests were conducted using a rotating drum to simulate a dry belt surface moving at speeds of 5, 6, and 7 meters per second [≈985, 1,181, and 1,378 fpm]. The tests were conducted for 30-minute periods using a primary cleaner blade of 90 Shore A durometer polyurethane. The test sequence showed blade temperatures at the contact point (blade tip) between 120° to 150°C [≈248° to 302°F]. Within 2 to 5 millimeters [≈1⁄32 to ¼ in.] away from the contact zone, the temperature of the urethane was reduced to 50° to 75°C [≈122° to 167°F], well under the temperature required to ignite belting.

A conscientious designer should be aware of the temperatures that might cause the specific conveyed material to burn. However, these test results indicate it is unlikely for sufficient frictional heat to build up in either urethane or metal belt-cleaner blades high enough to cause a belt and/or cargo to catch fire.

literature. It is the buyer's responsibility to verify the FRAS designation has been earned under the appropriate accreditation authority and testing procedures.

It is certainly good practice to look for the fire-retardant components accepted for use underground for all operations including those above ground.

Fire Detection Technologies for Conveyors

A fire associated with a conveyor system can be either a static fire—on a stationary belt or within the conveyor's mechanism or housing—or a moving hazard, like hot or burning coal riding on an in-motion conveyor belt. Each condition requires a different form of site-specific fire detection to guarantee fast, effective response and trouble-free operation.

The challenge in detecting these fires is that conventional fire detection systems are either unsuited to the environment (producing false alarms caused by dust or fog) or so insensitive that a fire can propagate and engulf the static conveyor before they activate.

Detection takes the form of heat sensing. Heat sensors will detect fires on moving or stationary belts, fires involving spillages and waste accumulations beneath the conveyors, overheated bearings and drive machinery, and heat buildup due to friction between the belt and structure or supports. As Verakis and Hockenberry noted in their 2008 paper, *Conveyor belt entry fire hazards and control*:

> Early fire detection through the use of carbon monoxide (CO) and smoke detectors, is critical to alerting miners and attending to a fire incident and can mean the difference between extinguishing a fire and having to contend with a fire that has grown out of control.

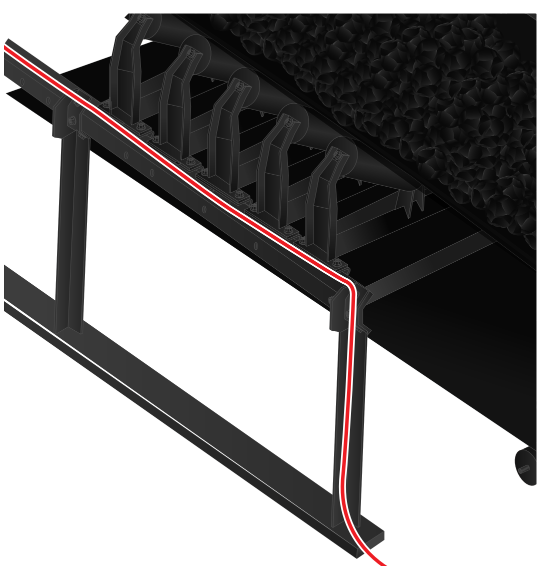


Figure 15.20.

Linear heat detector cables are typically installed beside the conveyor at a height of 1 to 1.5 meters [≈40 to 60 in.] above the belt.

According to Edward B. Douberly in an article, "Safety: Detecting Fires on PRB Coal Conveyors," published in *POWER* magazine in 2007, a variety of improved fire-detection methods are now available, including linear heat detection (LHD), infrared (IR) detection, and carbon monoxide (CO) detection systems.

Linear heat detectors work well on fixed fires (and stopped belts) but 'dwell time' requirements may limit their ability to detect flames on a moving belt. For early detection of static-type fires, linear heat detection cable has proven to be reliable when correctly installed (ideally at a height of 1 to 1.5 meters [≈40 to 60 in.] above the belt). (**Figure 15.20.**) LHD cables can also be placed between the belt and return belt.

A different challenge is created by fires on moving belts. According to Douberly, there are a variety of IR monitors currently suitable for detecting fires on moving conveyor belts. IR monitors fall into four main categories: thermal imaging systems, spark detectors, flame detectors, and IR black body emission detectors. Douberly reports some technologies work better for certain applications, and within each category various models with different features perform better than others.

The use of CO detection is becoming another method of early warning. Fires at transfer points and in conveyor tunnels have been detected by CO monitors where no other technique has been able to sense the incomplete combustion stage. But these areas need to be evaluated for air circulation; too much air circulation will disperse the CO before it can be detected.

A well-defined detection strategy that incorporates thermal, IR, and CO monitoring may ensure an early enough response that makes fixed extinguishing systems unnecessary.

Fighting Conveyor Belt Fires

Fighting fires on belt conveyors is difficult, due to the nature of the belting, the nature of the fire, and due to the nature of the environment where the conveyor is located. A fire in a belt conveyor can spread very quickly. Therefore, a fast-acting fire protection system that also can withstand the tough conditions in and around a belt conveyor is required.

Despite advances in firefighting technologies and fire suppressants, it is usually seen that water remains the best method of fighting a conveyor fire. As the 2010 NIOSH paper, *Improvements in Conveyor Belt Fire Suppression Systems for U.S. Coal Mines*, noted, "Water is a very effective method for suppressing and extinguishing belt fires; however, a sufficient supply of water is a necessity."

Fire suppression is usually achieved using water sprays or sprinklers. These systems may be omitted where the conveyor is partially or totally open and where well-trained and -equipped personnel are available for firefighting. Hydrants, equipment, manpower, and suitable access should be provided to facilitate manual firefighting. Hose reels can be provided at suitable locations so that all parts of the conveyor can be reached. Where the provision of hydrants is precluded by the length or location of the conveyor, water-carrying mobile equipment and pumps should be available.

In most cases, however, protection is vital over the head and tail sections of conveyors, drive motors, and important drive or transfer components, so sprinkler systems are installed. Coupled with effective fire-detection systems, an automatic sprinkler will offer reliable protection by automatically initiating a water-based suppression process. Sprinkler systems can also offer selective area firefighting: In the event of a fire, only the sprinklers located in the immediate proximity to the fire source will be activated. Immediate water-suppression action is taken, while the remaining sprinklers remain closed.

Sprinkler system design

According to the *Belt Conveyor Guidelines* issued as *GAP 9.3.1* by the global insurance and reinsurance company XL Global Asset Protection Services LLC, an automatic closed-head sprinkler or water spray should be provided when the conveyors have any of the following:

- Are fully enclosed or have limited access. ...
- Present a substantial business interruption potential.
- Are covered by combustible enclosures.
- Transport combustible materials.

Automatic closed-head sprinklers are adequate in most circumstances. A closed-head sprinkler is held closed by a heat-sensitive glass bulb or two-part metal fusible link which holds the system 'OFF' until the temperature rises enough to shatter the bulb or open the link, releasing water. In a standard system, each sprinkler activates independently, so only those sprinklers nearest the fire operate. This maximizes water pressure over the fire, while minimizing water damage elsewhere. (**Figure 15.21.**)

The *GAP Belt Conveyor Guideline* continues:

> In general, ceiling sprinklers adequately protect open conveyors inside buildings. However, if partial or full enclosures shield conveyors from overhead sprinklers, provide a fixed fire protection system covering the entire shielded area. Also provide sprinklers under conveyors over 4 ft [≈1.2 m] wide, because they obstruct the ceiling sprinklers.

Open sprinkler systems are often called 'deluge' systems. They provide a simultaneous application of water over the entire area of coverage, and so are typically used for hazards where rapidly spreading fire is a concern. The deluge valve is opened when signaled by the fire alarm system. Equipped with hydraulic, pneumatic, or electric triggers, deluge systems attack the fire quickly due to their open nozzles. They prevent reignition by cooling down the burnt objects. Deluge systems are suitable for use in areas where a fire can spread particularly quickly, such as coal conveyor systems. In certain high-risk areas, a film-forming foaming agent is added to the deluge system to reinforce the suppression effect.

According to the *GAP 9.3.1 Belt Conveyor Guideline* cited above, automatic open-head (deluge) water spray systems should be provided to protect conveyor belts and drives when conveyors have any of the following characteristics:

- Conveyor belts over 4 ft (1.2 m) wide.
- Stacked conveyor belts.
- Conveyors on steep slopes where a fire could overrun automatic sprinkler protection. Generally, conveyors inclined more than 30° present a high fire spread potential.
- Conveyors having frequent fires, such as coal conveyors.
- High-value conveyors or conveyors carrying high value materials.
- Conveyor belts with direct flame type de-icing systems.

Biodegradable chemical agents can be added to the sprinkler water supply to form micelles, or 'chemical cocoons,' around hydrocarbon fuel molecules. By bonding with the hydrocarbon molecules, the mixture effectively surrounds and permanently neutralizes the fuel and its vapors, rendering them non-flammable and non-ignitable. This encapsulation process provides permanent re-ignition resistance and quickly cools sprayed structures as well. During cleanup and subsequent disposal of the burnt belting or bulk materials, the fuel remains encapsulated, non-flammable, and non-ignitable, providing increased safety for firefighters and workers.

Another water-based system uses a mist- or fog-based system for conveyor fire control. Assuming equal firefighting efficiency, a

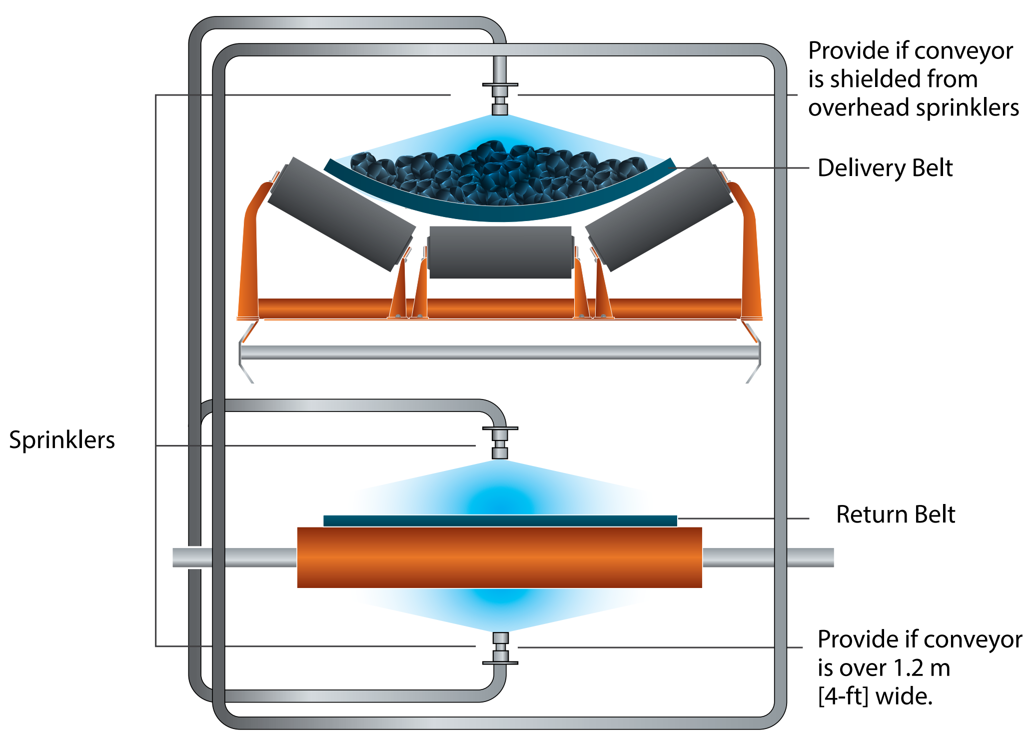


Figure 15.21.

Suggested points of application for a sprinkler system above a belt conveyor.

2

significant advantage is that this system uses considerably less extinguishing water when compared to deluge systems; one supplier claims a 70 percent reduction. Efficient fire protection and low consumption of water can reduce downtime and business interruptions following a fire. In addition, it is claimed the water mist reduces the ambient temperature during the extinguishing process; this, in turn, protects people.

United States Coal Mines as the Worst Case, and as a Model of Requirements

It is probably a valid assumption that a belt fire on a coal conveyor in an underground mine represents the 'perfect storm' of problems in conveyor fires. It presents the worst case in combustible material, the worst case in hazardous conditions for workers who need to evacuate and for those who fight the fire, and the worst case in difficulty reaching and maneuvering around the fire. In addition, the coal conveyor fire adds the danger of explosion as a secondary event, resulting from the fire-related dust generated in the confined space of a mine or gallery.

Consequently, MSHA offers detailed requirements for conveyor fire control systems. These requirements offer best practices for the application of fire prevention and suppression systems for all conveyor systems.

The regulations in *30 CFR* section 75.1101-7 Installation of water sprinkler systems: requirements, include the following:

(a) The fire-control components of each water sprinkler system shall be installed, as far as practicable in accordance with the recommendations set forth in National Fire Protection Association 1968-69 edition, *Code No. 13, Installation of Sprinkler Systems* and such systems' components shall be of a type approved by the Underwriters' Laboratories, Inc., Factory Mutual Research Corp.

(b) Each sprinkler system shall provide protection for the motor drive belt takeup, electrical controls, gear reducing unit, and the 50 feet [≈15 m] of fire-resistant belt, or 150 feet [≈46 m] of non-fire-resistant belt adjacent to the belt drive.

The following section, *30 CFR* section 75.1101-8 Water sprinkler systems; arrangement of sprinklers, includes:

(a) At least one sprinkler shall be installed above each belt drive, belt take-up, electrical control, and gear-reducing unit, and individual sprinklers shall be installed at intervals of no more than 8 feet [≈2.4 m] along all conveyor branch lines.

(b) Two or more branch lines, at least one of which shall be above the top belt and one between the top and bottom belt, shall be installed in each sprinkler system to provide a uniform discharge of water to the belt surface.

MSHA regulations in *30 CFR, Part 75.1100-1(a)* specify, "Waterlines shall be capable of delivering 50 gallons [≈190 l] of water a minute at a nozzle pressure of 50 pounds per square inch [≈3.5 kg/cm^2]." This is commonly referred to as the '50/50' rule.

In March 2011, MSHA reiterated key elements for compliance for water sprinkler systems and arrangements of sprinklers for underground belt conveyors and belt takeup storage units in a Program Policy Letter (PPL). This PPL, *No. P11-V-14*, additionally notes, "Wider belt conveyor installations may require more than one branch line directly over the top belt and … between the top and bottom belts" in order to "provide a uniform discharge" of water to the entire width of the belt surface.

Codes and Standards for Fire Protection

In addition to the agencies which regulate mining—and particularly underground mining—there are a number of standards and

2

codes for fire protection systems available. Perhaps the leading authority for consensus guidelines is the National Fire Protection Association (NFPA).

NFPA Codes which are particularly relevant include:

NFPA 13: Standard for the Installation of Sprinkler Systems

NFPA 15: Standard for Water Spray Fixed Systems for Fire Protection

NFPA 120: Standard for Fire Prevention and Control in Coal Mines

NFPA 652: Standard on the Fundamentals of Combustible Dust

NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids

NFPA 850: Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

In addition, Factory Mutual offers its *Loss Prevention Datasheet # 7-11 Conveyors*. This presents an overview and guideline for selecting fire-control systems and mitigating damage caused by a conveyor fire.

Relationships with the Fire Department

It is valuable and important that facilities form a close working relationship with their local fire department. Firefighters in community departments are likely unfamiliar with the requirements of fighting a fire in a bulk-handling facility, on the conveyor belts, or in other settings in the plant. An in-house emergency response team can be trained in proper firefighting techniques by the professionals in the community department; the fire department can be trained in the plant layout, and the particular hazards in that operation. By familiarizing the firefighters with the facility and the hazards, both the plant and the fire department are more comfortable with the preparations and the requirement for fighting a fire in plant. This improves safety for both plant personnel and firefighters.

Improving Fire Prevention

Improving the fire retardance of its belting is only one of the ways that an operation can reduce the risk of conveyor fires. The development of fire-retardant conveyor belting has made an important contribution to safety, but fire-retardant belts can burn in the presence of another fuel. Even the fibers torn or scrubbed from a misaligned belt can be ignited and will burn readily. A more flame-retardant belt will still burn if there is enough coal dust or grease to start a fire. These potential fire hazards can only be eliminated through high standards of conveyor installation, maintenance, and cleanliness.

Edward Douberly noted, “Prevention is your first line of defense against fires and explosions.” He listed the following preventative measures:

- Contain airborne dust at transfer points; remove dust that has accumulated on beams, pipes, conduits, equipment and fixtures; and minimize spillage from belts.
- Never allow stopped conveyors to stand with an undischarged load for an extended period.
- Minimize the accumulation of PRB coal [dust] below conveyors and on conveyor parts because it can spontaneously combust.

The report of the Belt Air Panel concurs in emphasizing fire prevention. The report’s Recommendation 5 states:

> The Technical Study Panel strongly recommends that the Federal Mine Safety and Health Administration (MSHA) rigorously enforce existing standards on underground conveyor belt maintenance and fire protection.

The recommendation continued:

> This applies especially with regard to the availability and functionality of belt fire suppression systems; the availability and proper working order of firefighting equipment; the function of smoke, carbon monoxide and other sensors and alarm systems designed to detect fires in belt entries; and the training of mine personnel for fighting mine fires, such as conveyor belts.

Particular attention should be paid to the:

> ... required examinations of the belt lines by mine examiners and ensure (1) each belt line is kept in good working order at all times to prevent belts from rubbing stands, (2) damaged rollers are replaced immediately, (3) belt lines [in coal mines] are adequately rock dusted, and (4) flammable materials such as fine coal, coal dust, oil, grease and trash are not permitted to accumulate along belt lines.

Other fire prevention measures should also be followed. As stated above, damaged rollers must be identified so that they can be replaced as soon as possible before the damage leads to frictional heating that can result in fire. Accumulations of combustible materials can not be permitted. Operators should use flame-resistant grease and other lubrications. Fire-detection and suppression systems and equipment must be tested in accordance to industry and regulatory standards.

Housekeeping is worthy of special emphasis in order to reduce the risk of belt fires. As Verakis and Hockenberry point out:

> The accumulation of combustible materials was the most frequently cited underground coal mine safety standard *(30 CFR 75.400)* by MSHA enforcement personnel in 2006.

Consequently, the cleanup of combustible materials, and particularly fugitive coal, is one of the most important fire-safety measures around belt conveyors.

Conveyor belt alignment is an essential prerequisite to belt safety. In saying the need for proper belt tracking is "amply illustrated" by the Aracoma Fire, the Belt Air Panel Final Report noted, "Examiners must ensure that the belt is properly aligned and trained to prevent frictional heating where the belt rubs against stands and other structure elements." (**See The Aracoma Mine Fire: Frictional Heat Leads to Tragedy.**)

Another significant fire-prevention measure is control of 'hot work' permits and procedures (for employees and outside contractors) and restrictions on the placement of flammable liquids and gases.

BEST PRACTICES
Conveyor Fire Prevention

In a report titled *The prevention and control of fire and explosion in mines*, the United Kingdom's Health and Safety Executive listed a number of best practices to minimize fire hazards around belt conveyors. The list includes:

- Using fire resistant conveyor belting;
- Ensuring that the conveyor is of sufficient capacity to carry the maximum expected load;
- Maintaining conveyor systems to ensure maximum specified loads on rollers and idlers are not exceeded;
- Using only drums, rollers and idlers manufactured to appropriate standards with suitable engineering tolerances;
- Using fire resistant fluids in hydraulic systems, traction couplings, etc.;
- Specifying fire-resistant grease in idler bearings;
- Using brake designs that are less vulnerable to sticking in the 'on' position and which are less prone to dust and other contaminants building up in the brake path;
- Installing monitors on vulnerable components to detect deterioration

or abnormal operation and providing appropriate protective devices;

- Designing and constructing transfer and loading points so as to minimize spillage and dust. They should be shrouded but have facilities for safe inspection and cleaning;
- Providing cleaning conveyors where necessary to remove spillage, particularly from beneath belt scrapers;
- Ensuring that all parts of the conveying system are accessible for inspection and can be safely cleaned;
- Using fire resistant materials in roadways at transfer and loading points.

In addition, conveyor housekeeping was emphasized, noting that conveyor drives, loops, return ends, and belt lines should be inspected regularly to ensure:

- Flammable materials, including coal dust and coal spillage, have not accumulated within or beneath them;
- Pieces of mineral are not wedged between moving parts and the conveyor structure;
- There is no leakage of lubricant from any drum or idler;
- There are no drums or idlers rotating with collapsed or seized bearings - any faulty roller should be replaced or removed until a replacement is available and can be fitted;
- That the belt is properly aligned and graded and is not rubbing against the roadside, fixtures and fittings, or any static element of the conveying system;
- All necessary safety devices are fitted and working;
- Belts are properly tensioned to avoid slipping.

The prevention and control of fire and explosion in mines report also emphasized the importance of monitoring, with the installation of the following additional systems recommended:

- Belt alignment devices need to be fitted at either side of the top belt as it arrives at the drive head and at other locations where frictional heating may result from the belt rubbing against some fixed object e.g. loop take ups, return and delivery units. They should be interlocked to stop the conveyor if they operate.
- Belt tear detection devices should be fitted at a safe run down distance from the delivery end such that the conveyor would stop before the torn belting went around the delivery roller.
- A [belt-slip] detector, arranged to stop the conveyor if belt slip leads to the belt speed falling below 75% of the speed of the conveyor drive drum, will help prevent frictional heating.

The *Belt Air Report* noted that best practices can minimize the fire risk. These procedures include:

1) Conducting regular belt examinations.
2) Removing accumulations of combustible materials along the conveyor.
3) Correcting potential sources of fire such as seized rollers, over heated bearings or belt misalignment.

These fire-prevention measures should be followed not only in those underground coal mining sites for which the Belt Air Panel conducted its investigation, but in all applications.

A few final Best Practices include:

- Verify the conveyor structure has an acceptable earth ground on a semi-annual basis.
- Patrol the belt to inspect rolling components during every shift.
- Maintain proper adjustment of those accessory components in contact with the belt.
- Respond immediately to remedy belt misalignment, failing idlers, and housekeeping issues.

- In case of a fire in a component or the belt itself, immediately shut down the conveyor to prevent propagation of the fire.
- Water is the most effective and available means to fight a conveyor fire.

The extent of fire-protection measures appropriate for a given application can only be determined once a risk analysis has been thoroughly evaluated.

CLOSING THOUGHTS
Conveyor Fires and Fire-Retardant Belting

Belt selection is a balance of performance and safety. Often increasing one category of performance, such as fire resistance, affects other belt properties, such as abrasion resistance. The trade-off between safety and belt life or any other property should be carefully considered.

In his comments to the Belt Air Panel, Bernd Küsel, Executive Vice President of Phoenix Conveyor Belt Systems GmBH, estimated that "self-extinguishing belts would cost 10 to 30 percent more" than belting certified to the previous MSHA standard. But, as he continued, "the benefits of increased safety and better operation and performance of self-extinguishing belts compensate for their increased costs."

Conveyor fires are a hazard to be sure, but one that can be mitigated by proper attention to details such as belt alignment and housekeeping. A 1967 United States Bureau of Mines report, *Fire Hazard of Conveyor Belts (Report of Investigations 7053)*, by Donald W. Mitchell, Edwin M. Murphy, Allan F. Smith, and Samuel P. Polack, noted that there are many aspects to conveyor fire control, saying:

> The fire hazard can be reduced by patrolling belts, inspecting rollers frequently, particularly after the belts have been stopped, and removing dirt build-up on return idlers and tail sections.
>
> The report further noted, Experience has shown that good fire-fighting facilities, clean belt systems and prompt action by the [workers] in the mine are the best defense against fire.

While making sure the belt is fire-retardant is just one step in preventing conveyor fires, it is a significant and critical one. It is doubly beneficial as it presents a method to minimize fire risks without adding the additional equipment expense, engineering and installation costs, or maintenance issues that the inclusion of secondary fire-control methods such as fire-detection and suppression systems will entail. With the proper selection of fire-retardant belting, many operations will be able to minimize or eliminate these secondary fire-control systems.

2

Chapter 16 Lighting

INTRODUCTION
The Challenge of Lighting Conveyors

Adequate lighting in work areas is necessary for the safety of the workers, productivity of the equipment, and quality of the completed work. Natural light may need to be supplemented by artificial lighting due to the size or design of the building, working hours, time of year, and weather conditions.

The illumination of interior work areas requires artificial lighting to make sure equipment can be inspected and its operation observed. Jacob Fruchtbaum's *Bulk Materials Handling Handbook* simply notes, "General illumination of operating areas should be such that routine inspection is possible during nighttime dark periods."

However, providing adequate lighting systems around belt conveyors can be a challenge. Conveyors stretch long distances, with overland systems commonly extending for kilometers. Some conveyors cross over plants, other conveyors originate underground or pass entirely through tunnels or enclosed passages.

Consequently, conveyor lighting systems operate in some of the most challenging environmental conditions for any lighting system. These lighting systems need to withstand vibration, temperature extremes ranging from -40 to 120° Fahrenheit [-40 to 50C°], high winds, rain, snow, humidity, insects, animals, and dusty conditions. The ability to withstand the tough industrial conditions of the conveyor's operating environment should be a major consideration when designing conveyor lighting systems.

The challenge for conveyor system lighting is to provide durable, low-maintenance systems that provide suitable amounts of lighting for safe working conditions. Unfortunately, such is often not the case and lighting is either not adequate or existing fixtures are not kept clean and working. Proper lighting and fixture maintenance contributes directly to a safe and productive work environment.

Minimum Lighting Requirements

Every task requires some level of lighting on the surface of the work. Good lighting is essential to perform visual tasks. Better lighting permits people to work with more productivity. Typical book reading can be done with 100 to 200 lux. Common sense tells us as more tasks are required or keener observations are required, more light is necessary. (**Figure 16.1.**)

The challenge is to choose the correct level of lighting for the conveyors to allow efficient inspection and maintenance without risk to workers. Commission International de l'Eclairage (CIE), Illuminating Engineering Society of North America (IESNA), and other groups have published recommended lighting levels for various tasks. These recommendations have since made their way into national and international standards for lighting design.

A minimum illuminance for all non-working interiors—a surface where work is not being performed—has been specified as 20 lux. The Australian standard *AS/NZS 1680.2.4:1997* specifically notes that conveyor and gantries (walkways) must maintain a minimum of 40 lux.

Commonly, this 40-lux standard is achieved by placing luminaires at 6 meter [≈19.5 ft] intervals along the length of the conveyor. Upgraded lighting systems have now allowed the extension of this spacing, allowing the luminaries to be placed as far as 12 meters [≈39 ft] apart to achieve the same lux levels. The benefits of this are obvious, as it means half the number of light fixtures to be purchased, installed, and maintained, and half the number of lamps burning electricity, which presumably results in lower electricity consumed.

The luminaires should be designed and installed so they are optimized for conveyor walkways and offer improved performance across the board. Proper fixtures and installation

Figure 16.1.

As tasks are more complicated or observations are more critical, additional lighting is necessary.

Lamps or Luminaires

When considering systems for conveyors—and other industrial installations—the fixture is commonly called a luminaire. While the lamp is the primary source of light, reflectors and dividers (or lamellae) are required to spread the light and direct it where it is needed. The luminaire is the apparatus that performs these functions. The luminaire can also act as a screen for glare and protects the lamp. It contains elements for distributing, filtering, and transforming the light emitted by a lamp and includes all items necessary for fixing and protecting the lamp(s) and for connecting to the power supply.

techniques can provide optimal illumination of conveyor walkways while minimizing the spill of light to the sides.

Of course, greater problems come with overland conveyors, where installation and maintenance of thousands of luminaries installed over kilometers of conveyors and walkways can be an expensive and ongoing burden.

REGULATIONS AND STANDARDS

In most case, there are no specific lighting standards for conveyors. Requirements typically cover lighting of general industrial or construction conditions, as well as the need for emergency lights. Some applicable standards are listed in **Figure 16.2**.

Foot-Candles, Lumens, Lux, and All That

As noted by Bruce W. Smith in a paper, *Developing a New Temporary Lighting System: From Identification of the Problem to the Design of the Solution*;

> Although there are many aspects to lighting, such as quantity, contrast, brightness, glare, and reflection, only quantity of light is measurable and used by the Occupational Safety and Health Administration (OSHA) in defining the minimum requirement of illumination.

Illuminance is the quantity of light falling on a unit area of surface; it can also be described as light level at the task. This is measured with a light meter in foot-candles (abbreviated as fc, fcd, or ftcd), or lux under International System (SI) units. A foot-candle is actually one lumen of light density per square foot; one lux is one lumen per square meter.

A foot-candle is defined as the amount of illumination the inside surface of a one-foot-radius sphere would be receiving if there were a uniform point source of one candela—that is, the light from a single, standard candle—in the exact center of the sphere. Alternatively, it can be defined as the illuminance on a one-square-foot surface of which there is a uniformly distributed light of one lumen. Thus one foot-candle is equal to one lumen per square foot or 10.764 lux.

As explained in the Wikipedia listing for foot-candle,;

> In practical applications, as when measuring room illumination, it is very difficult to measure illuminance more accurately than ±10%, and for many purposes it is quite sufficient to think of one foot-candle as about ten lux as is typically done in the lighting industry.

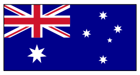
Examples of settings with the average recommended illuminance is measured in lux are shown in the table.

The accurate measurement of levels of illumination can be difficult, as explained by Patricia K. Clark, Director of OSHA's Director of Compliance Programs in a 1991 letter representing the agency's interpretation of *29 CFR 1926.56.* The letter, available on the agency's website, notes:

> The computation of illumination intensity at work level can be an extremely complex procedure. Many variables are involved such as: the specific light source, intensity, distance, atmospherics (air purity), floor, wall and ceiling color, and the respective surface sheens, to name a few. Therefore, the existing illumination level at any work surface within a work site is best measured with a light meter reading in lumens per square foot which are equal to foot-candles.

The letter further explains that light meters can be obtained at any photographic store.

Conditions	*Lux (lx)*
Outdoor sunlight, bright day, clear sky	30,000 to 100,000
Overcast day	1,000 to 5,000
Well-lit office interior	400 to 800
Minimum for easy reading	200 to 300
Warehouse aisles	100 to 200
House interior/Typical living room	50 to 250
Building corridors	50 to 100
Street light at night	15
Full moon on a clear night	0.25 to 1
Typical moonlight with a cloudy sky	0.1



Australia

The Australian conveyor standard *AS/NZS 4024.3610:2015 Safety of machinery – Conveyors – General requirements* contain standards for illumination in section 2.9. The standard first notes that lighting should be appropriate to the conveyor time and location of use, as compliant with the set of *AS/NZS 1680 Interior Lighting Standards.*

More specific illumination requirements are detailed in *AS/NZS 1680.2.4:1997 – Interior lighting Part 2.4: Industrial tasks and processes.* In its Table E1, this standard provides lighting recommendations for various industrial tasks and processes; these include section 38 Mines and Quarries (Surface Buildings) with subsections 38.1 Preparation plants and 38.2 Materials handling. (**Figure 16.3.**)

In a note for section 2.9.1, the *AS/NZS 4024.3610:2015* standard specifies that in underground mines, strict agreement with *AS 1680* is not required.

Further guidance for mining operations is included in standard *AS/NZA 4024.3611:2015 Safety of Machinery – Conveyors – Belt conveyors for bulk materials handling*. In its relevant passage—clause 2.7.2—it explains that in underground operations, lighting should be provided at every tipping point, such as crushers, transfer points, drive heads, and belt starters, as well as at main return pulleys and belt maintenance areas. For other underground locations, a cap lamp or other portable light is acceptable, according to the standard.

Canada

Again, regulations are unspecific. In section 21 Lighting, the *Occupational Health and Safety Act, Revised Regulations of Ontario (R.R.O.) 1990, Regulation 851: Industrial Establishments* notes merely:

> 21. Where natural lighting is inadequate to ensure the safety of any worker, artificial lighting shall be provided

Applicable Lighting Standards

Australia	*AS/NSZ 1680.0:2009 Interior lighting – Safe movement*
	AS 1680.1-2006 Interior and workplace lighting – General principles and recommendations
	AS 1680.2.1-2008 Interior and workplace lighting – Circulation spaces and other general areas
	AS 1680.2.2-2008 Interior and workplace lighting – Office and screen-based tasks
	AS 1680.2.3-2008 Interior lighting – Educational and training facilities
	AS/NZS 1680.2.4:1997 Interior lighting – Industrial tasks and processes
	AS/NZS 1680.2.5:1997 Interior lighting – Hospital and medical tasks
Brazil	*CIE 29.2-1986 Guide on interior lighting*
China	*GB 50034-2004 Standard for lighting design of buildings*
Europe	*EN 12464-1:2011: Light and lighting – Lighting of work places. Indoor work places*
	ISO 8995-1:2002 (CIE S 008/E: 2001): Lighting of work places – Part 1: Indoor
India	*IS 3646-1 (1992): Code of practice for interior illumination, Part 1: General requirements and recommendations for welding interiors*
	National Building Code of India 2005 (NBC 2005) [Part 8 Section 1]
Russia	*SNiP 23-05-2010 Daylight and Artificial Lighting: Construction Standards and Rules of Russian Federation*
South Africa	*SANS 10114-1:2005 Interior lighting Part 1: Artificial lighting of interiors*
USA	*ANSI/IESA RP-1-04 Recommended Practices for Office Lighting Training*

Figure 16.2.

Many countries specify standards for interior lighting.

and shadows and glare shall be reduced to a minimum.

In specifying minimal requirements for both standard lighting and for emergency illumination, the *Health, Safety and Reclamation Code for Mines in British Columbia* (issued by that province's Ministry of Energy, Mines and Petroleum Resources in 2008) is perhaps typical:

- Lighting Standards

  2.8.1 The manager shall ensure that at all working places, suitable and adequate illumination is provided meeting the standards set out in the *ANSI/IES Standard RP-7-1991: American National Standard Practice for Industrial Lighting*, as updated from time to time, unless otherwise authorized by the code.

- Surface Illumination

  2.8.2 The manager shall ensure that there is a separate and independent emergency source of illumination at all places where a hazard could be caused by a failure of the normal lighting system, and the emergency lighting system shall:

  (1) where it is a part of a permanent installation, turn on automatically when the normal lighting fails,

  (2) provide adequate illumination to allow employees to initiate emergency shutdown procedures and leave their work areas safely, and

  (3) be tested as frequently as necessary to ensure that it will function when required.

- Underground Illumination

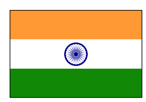
  2.8.3 The manager shall have suitable permanent lighting installed in an underground mine to provide adequate illumination in the following locations

  (1) all workshops, service garages, and other places where moving machinery or equipment could be a hazard,

  (2) main shaft stations and active shaft landings,

  (3) first aid stations, and

  (4) conveyor galleries, drives, and transfer stations.



India

Indian standard *IS 3646-1 (1992): Code of practice for interior illumination, Part 1 General requirements and recommendations for working interiors* (1992 Reaffirmed 2003) lists the following requirements

Figure 16.3.

Australian standard AS/NZS 1680.2.4 *specifies the required illumination levels for applications in mines and quarries.*

38 MINES AND QUARRIES (SURFACE BUILDINGS)	Type of interior or activity		Required Illumination Lux
38.1 Preparation plants	Working areas		240
	Picking belts		400
	Other areas		160
38.2 Materials handling	Conveyors and gantries		40
	Transfer houses	General	80
		Manned areas	160
	Silos and elevators		80
	Sampling towers		160
	Wagon loading		40
	Unloading points		40
	Other areas where operators are normally in attendance		160

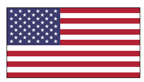
Abridged from Table E1 in AS/NZS 1680.2.4:1997 for general working areas related to conveyors. as shown in **Figure 16.4**.

South Africa

In the Republic of South Africa, the *Mandatory Code Of Practice For The Safe Use Of Conveyor Belt Installations For The Transportation Of Minerals, Material Or Personnel*, (Revision 2) from De Beers Consolidated Mines' Venetia Mine specifies the following in section 8.1.2.6 Illumination:

> The minimum lux intensity shall be 50 lux for head pulleys, tail pulleys, drives, loading points and 30 lux for the rest of the conveyor belt installation. Lights are to be positioned with sufficient illumination to all areas within the belt conveyor environment where significant risks are anticipated.
>
> Should it be determined by the Occupational Hygienist that levels of … illumination is not meeting acceptable standards; the Occupational Hygienist shall recommend improvements to the Engineer.

The minimum lighting requirement is repeated in *Venetia Mines' Code of Practice* in section 8.3.5 Belt Illumination, with the additional instruction that "Defective lights along conveyor belt installations shall be reported and logged onto a defect list for action by the responsible Senior Engineering Foreman."



United States

OSHA defers to the American National Standards Institute (ANSI) lighting standard—now updated as *ANSI/IES RP-7-1991*—for all activities except construction. As explained by Will Charpentier in his online article, "Factory Lighting Regulations":

<table>
<tr><th colspan="2">from Table 1 Recommended Illumination (clause 4.2.2.2)</th><th>Range of Service*
Illuminance in Lux</th></tr>
<tr><td>2. COAL MINING
(SURFACE BUILDINGS)</td><td>2.1.1 Walkways, floors under conveyors</td><td>30-50-100</td></tr>
<tr><td rowspan="2">3. ELECTRICITY GENERATION, TRANSMISSION AND DISTRIBUTION</td><td>3.2.1 Conveyors, gantries, junction towers, unloading hoppers, ash handling plants, settling pits, dust hopper outlets</td><td>50-100-150</td></tr>
<tr><td>3.2.2 Other areas where operators may be in attendance</td><td>100-150-200</td></tr>
<tr><td colspan="3">*4.2.2.2 Illumination ranges

Because circumstances may be significantly different for different interiors used for the same application or for different conditions for the same kind of activity, a range of illuminances is recommended for each type of interior or activity… Each range consists of three successive steps of the recommended scale of illuminances. For working interiors the middle value of each range represents the recommended service illuminance that would be used unless one or more of the factors mentioned below apply.</td></tr>
<tr><td colspan="2">The higher value of the range should be used when:
– Unusually low reflectances or contrasts are present in the task;
– Errors are costly to rectify;
– Visual work is critical;
– Accuracy or higher productivity is of great importance; and
– The visual capacity of the worker makes it necessary.</td><td>The lower value of the range may be used when:
– Reflectances or contrasts are unusually high;
– Speed and accuracy is not important; and
– The task is executed only occasionally.</td></tr>
</table>

Figure 16.4.

Indian standard IS 3646-1 *lists illumination standards for areas related to belt conveyors.*

2

That standard, ANSI/IES-RP-7-1991, takes a common sense approach to factory illumination that ensures optimum lighting based on "the functions and demands of the specific workplace setting." The standard, like all consensus standards, is constantly under review to ensure an inclusive nature that accounts for new technologies, such as LED lighting, and new, ongoing research. Because innovation and research might cause ongoing changes in the standard, OSHA incorporates the standard in its regulations by reference, rather than by copying specifics.

OSHA recommends employers use this standard as a guideline to determine the sufficient lighting required to provide for the safety and health of employees in workplaces.

The OSHA construction industry standard *29 CFR 1926.56 Illumination* has very specific illumination requirements for construction sites, while general industry standards are much broader and rarely specify illumination requirements. The standard in *OSHA 29 CFR 1926* established minimum lighting requirements in foot-candles—the amount of illumination produced by a candle from 1-foot distance—for a variety of work environments while any work is in progress.

Specific minimum illumination requirements for construction sites are spelled out in *29 CFR 1926.56(a)* in Table D-3: Minimum Illumination Intensities in Foot-Candles (**Figure 16.5.**)

For any other areas, *CFR 29 1926.56(b)* specifies that recommended Illumination values are spelled out in *American National Standard A11.1-1965, R1970 Practice for Industrial Lighting*.

Emergency Lighting

OSHA's regulations for Means of Egress in *29 CFR 1910.37(b)* says, "Lighting and marking

2

Figure 16.5.

In the United States, OSHA minimum illumination requirements are specified in 29 CFR 1926.56.

Foot-Candles	Areas of Operation
5	General construction area lighting.
3	General construction areas, concrete placement, excavation and waste areas, access ways, active storage areas, loading platforms, refueling, and field maintenance areas.
5	Indoors: warehouses, corridors, hallways, and exitways.
5	Tunnels, shafts, and general underground work areas: (Exception: minimum of 10 foot-candles is required at tunnel and shaft heading during drilling, mucking, and scaling. Bureau of Mines approved cap lights shall be acceptable for use in the tunnel heading.)
10	General construction plant and shops (e.g., batch plants, screening plants, mechanical and electrical equipment rooms, carpenter shops, rigging lofts and active store rooms, mess halls, and indoor toilets and workrooms.
30	First aid stations, infirmaries, and offices.

Figure 16.6.

Illuminations standards from the Washington Administrative Code.

Lighting Table (Foot-candles)		
Activity	Minimum acceptable average lighting level in an area:	Any one single measurement used to determine the average lighting level* cannot be less than:
Indoor task	10	5
Outdoor task	5	2.5
Nontask activities for both indoor and outdoor	3	1.5

* Lighting levels must be measured at thirty inches above the floor/working surface at the task.

must be adequate and appropriate." Further, *1910.37(b)(1)* specifies, "Each exit route must be adequately lighted so that an employee with normal vision can see along the exit route."

MSHA Requirements

In its regulations for Metal and Nonmetal Mines, the Mine Safety and Health Administration (MSHA) merely specifies, in *30 CFR Subpart P – Illumination sections 56* and *57 17001 Illumination of surface working areas*:

> Illumination sufficient to provide safe working conditions shall be provided in and on all surface structures, paths, walkways, stairways, switch panels, loading and dumping sites, and work areas.

No additional details are provided.

State Requirements

Some states in the United States get more specific in their requirements. Section R614-5-2 Conveyors G Illumination of Rule R614-5 Materials Handling and Storage from the *Utah Administrative Code Title R614 Labor Commission, Occupational Safety and Health* says:

> Sufficient lighting to see the equipment clearly shall be provided at floor level, head and tail pulleys, operating stations and along conveyor systems which must be inspected - 5 to 10-foot candles of light meet this requirement.

In *WAC 296-800-21005*, the *Washington Administrative Code* mandates an operation must "provide and maintain adequate lighting for all work activities in your workplace," and offers additional detail in **Figure 16.6**.

WAC 296-800-21005 further stipulated that a plant must:

> ... have adequate light for employees to see nearby objects that might be potential hazards or to see to operate emergency controls or other equipment, if general lighting is not available.

The Michigan Department of Licensing and Regulatory Affairs, notes in its *General Industry Safety Standards, Part 14. Conveyors, R408.11426 Passageways and walkways*:

> (3) A walkway along a conveyor in a pit or tunnel shall have illumination of at least 10 foot candles when an employee is required to work in an area.

Considerations on Lighting Design

The provision of sufficient light is (almost) a given. (**Figure 16.7.**) The 'value added' to be sought in the selection of the fixtures and the entire lighting system includes other attributes of the luminaire, including durability, maintainability, and energy efficiency.

General lighting requirements can be augmented with additional lighting that is either permanent or portable for critical operations and used only when necessary.

Luminaries for use underground in mines or tunnels—and/or in coal handling or other explosive environments—will have special requirements, including explosion-proof construction. These features are not otherwise discussed in Best Practices

BEST PRACTICES
Lighting for Conveyors

The following are some Best Practice considerations for a conveyor lighting system:

Figure 16.7.

Luminaires used for conveyor applications should feature robust construction to withstand rugged conditions.

- Luminaires should be designed for use in the harsh environments of conveyor applications, to endure arduous conditions, including vibration, dust, moisture and adverse temperatures.
- Robust construction means that it can withstand the constant shock and vibration commonly experienced in the bulk-materials-handling environment.
- Fixtures should be easily installed, accessible, and designed for easy cleaning and relamping without the use of ladders or specialized equipment.
- Light fixtures should be designed to minimize the buildup of fugitive materials.
- Enclosures should comply with NEMA 4 or 4X or IP65 or 66.
- Fixtures should be weather-tight, including the ability to withstand a high-pressure washing.
- For outdoor systems, a daylight sensor should be incorporated, so the system can turn itself ON and OFF.
- Lighting under the conveyors should also be considered to assist with regular cleaning and maintenance.
- Emergency lighting should be included in the system at the design stage.
- Power sources for portable task lighting equipment must be conveniently located.
- Inspectors and maintenance personnel have access to portable spot lamps that generate at least one million candlepower.

Best practices for conveyor lighting include area illumination to the following standards show in **Figure 16.8**.

CLOSING THOUGHTS
The Light Fantastic

Lighting is required to provide a safe environment for personnel walking beside conveyor belts. (**Figure 16.9.**)

Lighting is required for safe inspection, maintenance and operation of conveyors. Properly

2

Figure 16.8.

Best Practices for Illumination around Belt Conveyors.

Description	*lux*	*Notes*
Walkways (Open or in Gallery)	40	
Tail Pulleys, Loading Chutes, Discharge Chutes, Drives, and Takeup Stations	80	This also includes other areas that require frequent cleaning under and around conveyors.
Inspection and Maintenance	160	Permanent or portable auxiliary lighting can be used to reach this level.

Enclosure Ratings: NEMA or IP

The 'NEMA 4' rating indicates the "enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against" incidental contact with the enclosed equipment; "to provide a degree of protection" against falling dirt, rain, sleet, snow, windblown dust, splashing water, and hose-directed water; and that will be undamaged by the external formation of ice on the enclosure. The 'NEMA 4X' rating is similar, with the only difference being the addition of corrosion protection.

The International Protection Marking system (or IP Code) uses a two-digit number to indicate the level of protection provided by an enclosure. The first digit represents protection against the ingress of foreign objects such as solid particles (dust); '6' is the highest rating and indicates 'Dust tight.' The second digit indicates the level of protection against ingress of liquids (water). For more information, consult *ANSI/IEC 60529 Degrees of Protection Provided by Enclosures (IP Code).*

designed lighting systems provide the conditions that allow those chores, while minimizing the expense for the installation and operation of the lighting system.

Adequate lighting is needed to properly assess the state of the conveyor. Lighting can illuminate—in all senses of the word—the problems of conveyor systems: mechanical difficulties, fugitive material, safety concerns, and other challenges. ⚠

Figure 16.9.

Sufficient lighting is required to allow workers to walk beside a belt conveyor.

2

2

Chapter 17 Dust

INTRODUCTION

Material escaping from conveyors is an everyday occurrence in many plants. Fugitive material arises as spillage and leakage from transfer points, carryback that has adhered to the belt past the discharge point and is dislodged along the conveyor return, or as dust that has been carried off the belt by currents of air and the forces of loading.

Fugitive material has been around plants since conveyors were first operated, and for a long period of time it was accepted as part of doing business. But these fugitive materials can create health and safety hazards. Because the airborne dust can spread farther than the other forms of fugitive material, and because the other forms of fugitive material can also be picked up by the air and carried away as dust, dust has attracted more attention with governments and regulatory agencies all over the world.

Although airborne dust can be created by traffic on haul roads, windblown from stock piles, or released by crushing and other process steps, this volume will not discuss these sources. The focus of this chapter is dust produced by bulk-material handling, specifically by belt conveyors.

The Definition of Dust

Dust can be broadly defined as very small solid particles created by the fracture of larger particles.

After considering various definitions, the World Health Organization's publication, *Hazard Prevention and Control in the Work Environment: Airborne Dust,* arrived at this summary definition:

> Dusts are solid particles ranging in size from below 1 µm [micron] up to at around 100 µm [micron], which may be or become airborne, depending on their origin, physical characteristics and ambient conditions.

Dust is produced when a solid is broken by impact, crushing, abrasion, grinding, drilling, demolition, shoveling, conveying, screening, bagging, or sweeping. Dust becomes airborne when dry material is moved, manipulated, or subjected to air currents. (**Figure 17.1.**)

Depending on their size, particles of dust can become hazardous to worker health, particularly when suspended in air. According to *Dust Control Handbook for Industrial Minerals Mining and Processing* published by the United States National Institute for Occupational Safety and Health (NIOSH),

> The largest size particle that can be suspended in air for long periods of time from wind velocity acting upon it is about 60 micrometers [or microns (µm)] which is about the thickness of a human hair.

Small airborne particles of dust, which can remain suspended in air for hours, pose a greater risk to the respiratory system when inhaled. In general, the smaller the aerodynamic diameter of the inhaled dust particle,

2

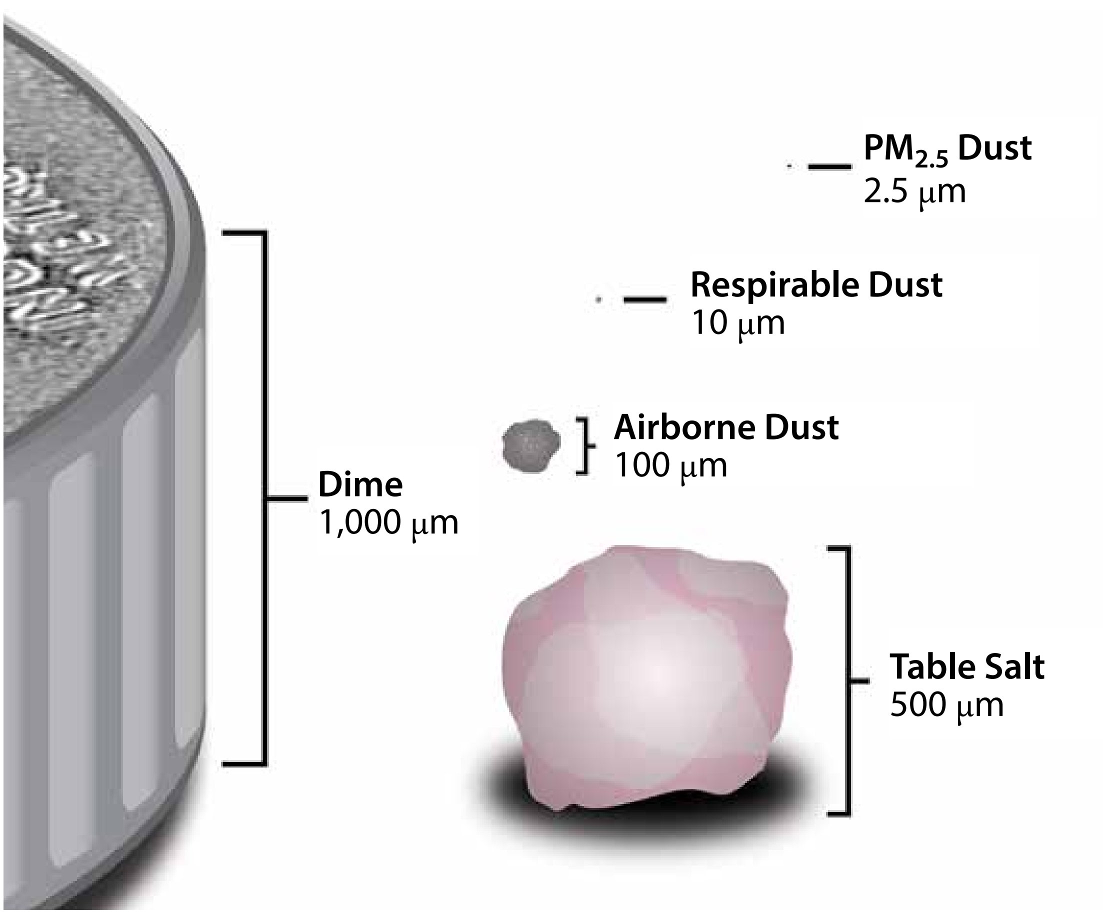


Figure 17.1.

Dust particles are tiny, 2.5 micron particles which can barely be seen even with significant magnification.

(Not to Scale)

Particulate Matters

Airborne particles are sometimes referred to as 'particulate matter' or 'PM.' These particles include dust, dirt, soot, smoke, and liquid droplets. Some particles are large enough or dark enough to be seen as soot or smoke, while others are so small they can only be detected through a microscope or other sensitive equipment.

Some particles are emitted directly into the air from a variety of sources that are either natural or related to human activity. Natural sources include bushfires, dust storms, pollens, and sea spray. Those related to human activity include motor vehicle emissions, industrial processes (such as electricity generation and stone crushing), unpaved roads, and wood-burning heaters.

Particles can be classified on the basis of their size, referred to as their 'aerodynamic diameter.' Big particles are between 2.5 and 10 micrometers (microns or μm). This is 25 to 100 times thinner than a human hair. These particles are termed PM10 (or PM_{10}), and pronounced 'P M Ten, which is short for 'Particulate Matter up to 10 Micrometers.'

Smaller particles up to 2.5 micrometers are called PM2.5 (or $PM_{2.5}$) which is pronounced 'P M Two Point Five.'

These 'PM' names are seen in governmental regulations for time-weighted levels of air quality, including vehicle emissions and from coal-burning power plants.

Both the PM_{10} and the $PM_{2.5}$ particles can cause problems with respiratory health with the lungs and airway. Health effects include the following:

- Coughing, wheezing, shortness of breath
- Aggravated asthma
- Lung damage (including decreased lung function and life-long respiratory disease)
- Premature death in individuals with existing heart or lung diseases

Because the smaller particles travel deeper into the lungs, the smaller particles of $PM_{2.5}$ dust can have worse health effects than the larger PM_{10} particles.

the more likely it will be deposited more deeply in the respiratory tract. Hence these particles are called 'respirable dust.' While dust in general is a nuisance and can be a hazard, it is this respirable dust that leads to significant health risks.

The Hazards of Dust

There are three general categories of worker hazards arising from dust: diseases of the lungs, fire and explosions, and general safety risks.

Diseases of the Lungs

Some materials have specific health-related limits on dust exposure; other materials do not. But this does not mean that these non-regulated dusts are acceptable. (**Figure 17.2.**)

There are a number of respiratory diseases caused or exacerbated by breathing dust-laden air. These diseases include asthma, emphysema, black lung, and silicosis. One of these diseases is pneumoconiosis, a term proposed by a researcher in 1866 as a general term for lung diseases caused by dust inhalation. Black lung is the common name for Coal Workers' Pneumoconiosis (CWP) which results from inhalation of respirable coal dust. Silicosis results from inhalation of respirable silica dust. Both lung diseases can be disabling or fatal in their severe form.

Fire and Explosion

The familiar 'Fire Triangle' shows the three sides or requirements of a fire. They are:

- Fuel – Something to burn
- Ignition – Something to set it off
- Oxygen – Something to keep it going

A dust explosion is the rapid combustion of fine particles suspended in the air, often but not always in an enclosed location. In order to expand from a fire to an explosion, the familiar fire triangle becomes a pentagon, adding two sides or requirements to the familiar fire triangle. (**Figure 17.3.**) These sides are:

- Dispersion – Dust must be dispersed to make it airborne
- Confinement – Energy must be contained, such as inside a building

Dust explosions can occur where any dispersed powdered combustible material is present in high enough concentrations in the atmosphere.

Dust explosions are characterized by an initial (primary) explosion in an area where fugitive dust has accumulated. This initial blast may shake loose accumulated dust or damage a containment system (such as a duct, vessel, or collector). The bad news is that the additional dust dispersed into the air by the primary explosion may cause one or more secondary explosions. These can be far more destructive than the primary explosion. Fatalities more often come from secondary explosions, as they are more destructive and far-reaching.

Generally speaking, fire and explosions are risks with dusts of organic origin, such as coal, grain, sugar, and wood dusts. In addition, some metal dusts are explosive, although these dust are less likely to be encountered in operations using belt conveyors.

General Safety Risks

Even when the hazards from dust are not as catastrophic as an explosion, or as serious as long-term lung disease, they can be significant. Dust can lead to accidents and injuries in several other ways.

Slips, Trips, and Falls

Dust accumulations can make walkways and stairs slippery or even block them. Dust and moisture—from rain, snow, or even from dust suppression systems—can combine into a slime that makes footing particularly treacherous. The result is a slip/trip/fall accident that will injure a worker. The resulting slip/trip/fall accident can also put the worker at risk of falling onto or into a moving belt or rolling component, risking more serious injury.

Poor Vision/Visibility

Even when dust is not flammable or toxic, it can lead to accidents through reduced visibil-

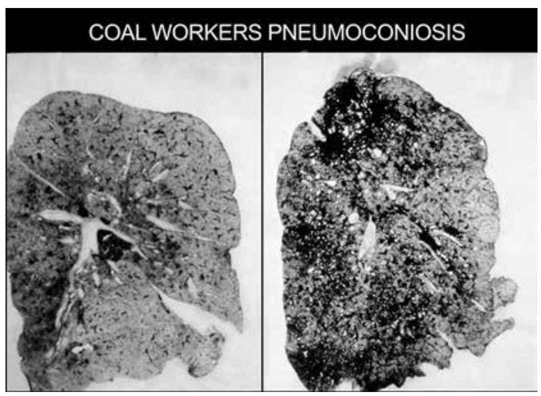


Figure 17.2.

Working in dusty conditions can lead to health issues including Coal Workers' Pneumoconiosis (shown on right; normal lung on left). Image courtesy of CDC

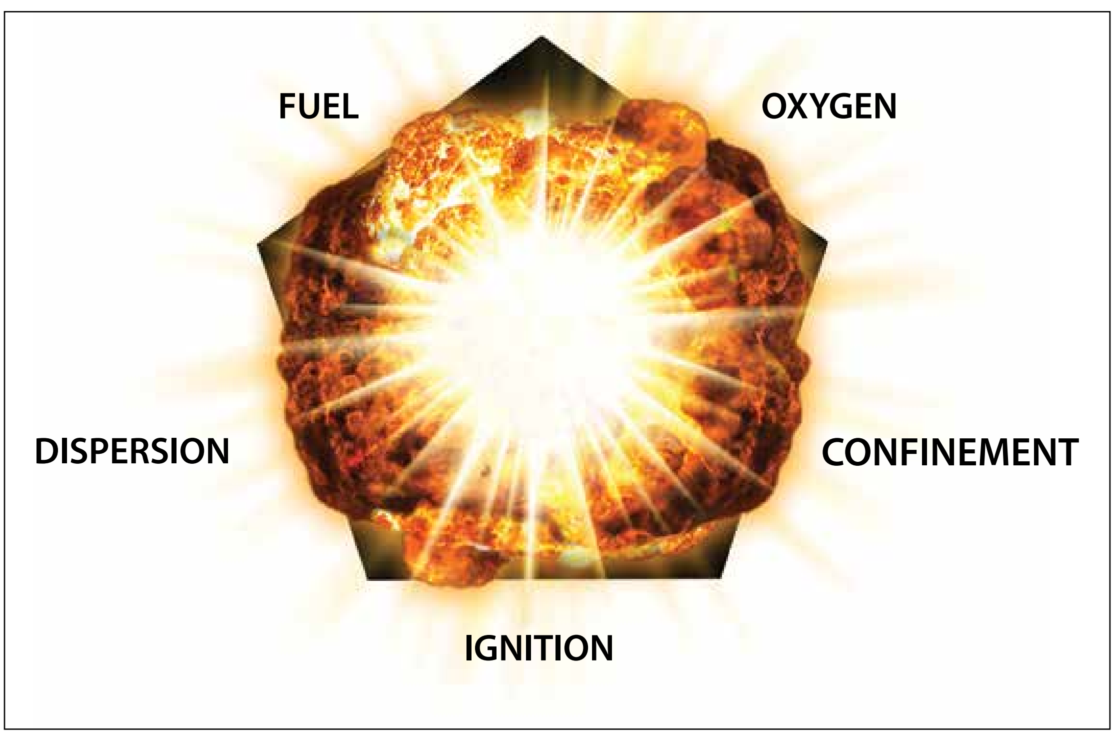


Figure 17.3.

When dispersion and confinement are added, the 'fire triangle' becomes an 'explosion pentagon.'

2

ity. When there is a dusty environment, there is added difficulty for workers to see warning signs, moving conveyor belts and rotating parts, and other hazards. In addition, there is difficulty for the operators of vehicles and heavy equipment to see other vehicles or individual workers on foot.

Figure 17.4.

Wearing protective garments and dust masks or respirators can interfere with a worker's comfort and ability to perform assigned tasks.

Worker Discomfort

Even the protective measures used to prevent dust-related disease can lead to accidents. (**Figure 17.4.**) The wearing of respirators causes problems in vision and breathing. They also can interfere with a worker's range of motion—that is, the comfort level and ability to work—and perhaps even willingness to work. These changes can lead, in turn, to injuries.

The Basics of Dust Management

The behavior of dust can be explained as a relationship.

As shown in **Figure 17.5**, the relationship of the amount of dust generated is proportional to the air velocity and inversely proportional to the particle size and the material cohesiveness.

This relationship is explained in the following passage from Chapter 7, Air Control from Martin Engineering's *FOUNDATIONS™*,

Explosive Potential

According to the article, *Combustible Dust: Complying with OSHA Regulations and Preventing the Hazards of Combustible Dust*, by Charles B. Palmer and Reince R. Priebus, the National Fire Protection Association (NFPA) says that combustible dust is:

> … finely divided solid material that is 420 microns [μm] or smaller in diameter (material passing a U.S. No. 40 Standard Sieve) and presents a fire or explosion hazard when dispersed and ignited in air.

But determining if a material is an explosion risk is not as simple as it might seem. The same Palmer and Priebus article noted "a material need not generally be combustible in its original form to become combustible dust when broken down into fine enough particles."

Palmer and Priebus continue:

> The NFPA recommends several practices and policies to prevent combustible dust explosions, including:
>
> - minimizing the escape of dust from processing equipment or ventilation systems;
> - use of dust collection systems and filters and surfaces that minimize dust collection;
> - inspect and clean dust accumulations in hidden and open areas regularly;
> - use cleaning methods that do not create dust clouds (such as wet processes or vacuuming);
> - use appropriate electrical equipment and wiring methods;
> - controlling static electricity, smoking, open flames, sparks, and friction;
> - install and use spark/ember detection, extinguishing, sprinkling, and explosion protection systems.

Many commercial testing laboratories offer a low-cost test to establish whether a dust sample is combustible. If the test is positive, then the explosive index (K_{st}) and the maximum pressure rise (P_{max}) of the dust should be determined; a supplier for dust collection systems will use these values to correctly size explosion-venting or explosion-suppression systems.

The Practical Resource for Cleaner, Safer, More Productive Dust & Material Control, Fourth Edition (**See Martin's *FOUNDATIONS™* Book Offers More on Controlling Dust**):

> As materials move on a conveyor and through the transfer point, they carry a stream of air in and with them. With sufficient velocity, this air stream can pick fine particles out of the material body and carry them along with the materials, or it can spread them outside the enclosures of the conveyor.
>
> The conditions that determine whether or not fine materials become airborne are air velocity, particle size, and cohesion of the bulk materials. These characteristics contribute to the amount of dust generated by the following intuitive, relative relationship: The amount of dust generated is proportional to air velocity, as divided by the factors of particle size and material cohesiveness.
>
> Where one or more of these parameters is a given, the ability to control dust depends on altering one or both of the other characteristics. If air velocity is increased, but particle size and cohesiveness remain constant, then airborne dust will increase. If air velocity remains constant and particle size or cohesiveness is increased, the amount of airborne dust will be reduced. If velocity remains constant, and particle size or cohesiveness is decreased, then the amount of airborne dust will increase.
>
> When the size of particles being conveyed cannot be changed, the velocity of the air or the cohesive force of the particles must be altered in order to minimize the emission of dust.* … Control of the air movement into and out of a conveyor transfer point will not reduce the dust created inside that transfer point, but it will have a significant effect on the amount of dust that is carried out of the transfer point. Limiting the positive pressure released by a transfer point will have significant benefits in the control of fugitive materials.
>
> * The material from Chapter 7 Air Control refers to Chapter 19 Dust Suppression in *FOUNDATIONS™, Fourth Edition*.

Material-handling techniques that decrease the air velocity, and/or increase particle size or increase material cohesiveness will decrease the amount of airborne dust released.

REGULATIONS AND STANDARDS

The standards that exist are not written to specifically cover dust that is conveyor-related. Rather, the standards are geared to regulate all dust produced by all processing and handling procedures in a facility and its surrounding environment.

It is more common that explosive dusts are regulated. The presence of other dusts is sometimes regulated, but the hazard inherent in coal, grain, and other explosive dusts means that the handling of these materials will be subject to much stricter regulations and more vigilant enforcement.

Standards and regulations for dust are subject to measurement and adjustment. For example, the regulations covering exposure to silica dust in the United States are under review at the time of this writing, with ongoing discussions between regulators and the concerned industries disputing the appropriate levels. This is a case that demonstrates that regulations in general—and dust regulations in particular—are subject to frequent change and

$$\text{Dust Generated} \propto \frac{\text{Air Velocity}}{\text{Particle Size} \cdot \text{Cohesiveness}}$$

Figure 17.5.

Relationship between the release of dust, air velocity, particle size, and material cohesiveness.

should be reviewed carefully. The user should seek counsel from experts in regulations and in measuring dust levels to verify compliance with applicable standards.

Australia

Airborne dust in a workplace should not exceed the maximum concentration for the type of dust as specified in the relevant mining, quarrying, or industry regulations, or the levels specified in *Workplace Exposure Standards for the Airborne Contaminants*, as issued in 2013 by Safe Work Australia.

Relevant industry standards for dust control include Australian standards *AS 2895-2004 Workplace Atmospheres – Method for Sampling and Gravimetric Determination of Respirable Dust* and *AS3 640 – 1989 Workplace atmospheres – Method for sampling and gravimetric determination of inhalable dust.*

Canada

Alberta's Occupational Health and Safety Code (2009) Part 36 (Mining) has dust regulations in several sections. Section 601 Combustible Dust contains this reference:

> 601(1)
> An employer must ensure that, in hazardous locations, no combustible dust accumulates at or near the conveyor belt, the belt support rollers, the conveyor belt drive and tail or the belt take-up drums.
>
> 601(2)
> An employer must ensure that, if dust may be a hazard, a belt conveyor discharge is constructed so that the amount of dust spilled or dispersed into the air is minimized or eliminated.

Section 742 Airborne Dust includes the following:

> 742(1)
> An employer must ensure that there is a water supply designed to suppress airborne dust.
>
> (a) at a location where mineral is transferred from one conveyor to another conveyor, a chute or a vehicle, and

Martin's *FOUNDATIONS*™ Book Offers More on Controlling Dust

The creation and control of conveyor dust are covered in greater length in Martin Engineering's book *FOUNDATIONS™, The Practical Resource for Cleaner, Safer, More Productive Dust and Material Control, Fourth Edition.*

For nearly 20 years, Martin Engineering's *FOUNDATIONS™* books have taught industry personnel to operate and maintain clean and safe belt conveyors.

Published in 2009, the fourth edition of the *FOUNDATIONS™* book is a 576-page hardcover authoritative reference on the 'Whys' and 'Hows' to improve conveyor productivity and provides a thorough discussion on topics and techniques for enhancing the performance of belt conveyors.

FOUNDATIONS™ covers conveyors with a comprehensive, real-world approach. It features topics ranging from basic components of belt conveyors to the calculation of air flow and the analysis of material properties. It takes readers from the basics of why conveyors run as they do—and where their problems come from—to the methods to prevent spillage, dust, and carryback, to correct tracking, and to engineer a conveyor belt-washing system.

The Fourth Edition of *FOUNDATIONS™* is now published in English, Portuguese, Spanish, German, French, Italian, and Russian editions and is available in hardcopy and digital format.

For information, visit *martin-eng.com* or contact a Martin Engineering representative.

(b) at the cutting teeth or picks of a coal cutting machine.

742(2)
Subsection (1) does not apply to a location where mineral is conveyed from the conveyor of a mobile unit.

742(3)
An employer must ensure that a roadway used by rubber-tired vehicles is treated or wetted to minimize the creation of airborne dust.

742(4)
An employer must ensure that there is an ongoing program for monitoring the concentration of respirable dust to which workers are exposed.

742(5)
The Director may require an employer to install dust collection devices on exhaust fans if the Director considers that conditions warrant doing so.

Section 743 is principally concerned with the use of rock dust in underground coal mines, although the following passage is appropriate to a discussion of fugitive dust.

743(1.1)
If reasonably practicable, an employer must ensure that every area in an underground coal mine is kept free of accumulations of coal dust.

The *Health, Safety and Reclamation Code for Mines in British Columbia* includes the following requirement:

6.24.2
Wherever practicable, water sprays or other dust suppression means and devices shall be used at every dusty place where work is carried out and where it is impractical to do so, personal protective equipment shall be supplied ...

The Province of Quebec's *Regulation respecting occupational health and safety in mines* includes this passage:

98. Whenever dust is created by movement of rock, materials or mobile equipment, some means of control, such as calcium, water or foam, shall be used to reduce or prevent the emission of the dust.

Europe

DIN EN 620 Continuous handling equipment and systems – Safety and EMC requirements for fixed belt conveyors for bulk materials contains the following instructions:

5.5 Measures for protection against fire and explosion hazards due to the materials conveyed

If the equipment may be required to convey finely divided materials (dusts), with a possible risk of fire and explosion, then it shall comply with the requirements in Annex A.

Annex A Fire or explosion hazard, after noting that the equipment shall be designed to minimize the risks, in accordance with *EN 1127-1:1997*, specifies:

Many finely divided organic materials, both natural and synthetic are capable of causing dust explosions. Some metal and inorganic materials are also explosible. A powdered material is unlikely to cause a serious explosion risk unless it contains a significant proportion of dust of particle size less than 200 microns. If there is a possibility that a powder to be handled is explosible, then it should be tested. A method of test is given in *ISO 6184-1:1985*.

DIN EN 620 Annex A includes the following:

Where a concentration of these dusts represents a risk of explosion, then precautions shall be taken to remove these dusts at their source, especially at transfer points and in hoppers. If necessary, explosion venting or suppression equipment shall be fitted, particularly to totally enclosed equipment.

2

Risk of fire or explosion shall be minimized, by e.g.:

- positioning sources of ignition outside the dusty area, e.g. bearings, items with mechanical friction or impact;
- using electrical equipment suitable for hazardous areas zone 20, 21 or 22 (see *IEC 61241-1-1:1999* and *EN 1127-1:1997*);
- anti-static measures (see 5.2.2);
- using speed and rotation detectors, where there is risk of sparks from failed mechanical components (see 5.7.2.11);
- using indicators, detection means and/or overload detectors where there is risk of jamming or blocking, (see 5.7.2.11).

South Africa

SANS 1929 (2011) Ambient air quality – Limits for common pollutant specifies limits for PM_{10} and $PM_{2.5}$.

SANS 1929 also contains regulations for ambient dust deposition, including the thresholds for target, remedial action, and notification of the authorities. The reference method for measuring dustfall shall be *ASTM D1739 Standard Test Method for Collection and Measurement of Dustfall (Settleable Particulate Matter)*. Dust deposition rates are expressed in units per day over a 30-day average period. Allowance will be given for dustfalls over the specified rates that can be shown to be the result of some extreme geological or weather event.

Similar requirements are presented in the *National Environmental Management: Air Quality Act, 2004 National Dust Control Regulations*. This regulation requires in section 4.2:

> Any person who conducts any activity in such a way as to give rise to dust in quantities and concentrations that may exceed the dustfall standard set out in regulation 3 must, upon receipt of a notice from the air quality officer, implement [a] dust fall monitoring programme.

In addition, section 6.2 requires that within three months, this person submit a dust management plan which must:

(a) identify all possible sources of dust within the affected site;

(b) detail the best practicable measures to be undertaken to mitigate dust emissions;

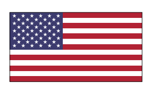
(c) detail an implementation schedule;

(d) identify the line management responsible for implementation;

(e) incorporate the dust fallout monitoring plan; and

(f) establish a register for recording all complaints received by the person regarding dustfall, and for recording follow up actions and responses to the complainants.

SANS 1929:2011 specifies the reference method for the determination of the $PM_{2.5}$ fraction of suspended particulate matter shall be *EN 14907,* a document now superseded by *DIN EN 12341:2014-08 Ambient air – Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2.5}$ mass concentration of suspended particulate matter*.



United States

According to the article, *Combustible Dust: Complying with OSHA Regulations and Preventing the Hazards of Combustible Dust*, by Charles B. Palmer and Reince R. Priebus, the United States Occupational Health and Safety Administration (OSHA) will issue a citation for the presence of combustible dust under this standard if dust accumulations:

1) Exceed 1/32 inch [≈0.8 mm] deep [roughly the thickness of a standard paper clip].
2) Cover at least 5% of a room's total area or 1,000 square feet [≈93 m^2] (whichever is less).

3) Are combustible.

Although OSHA's housekeeping regulations in 29 *CFR 1910.22* have no specific wording that addresses fugitive dust, it has been applied to dust accumulation hazards. In *1910.22(a)(1)*, the standard reads: "All places of employment, passageways, storerooms, and service rooms shall be kept clean and orderly and in a sanitary condition."

Other OSHA regulations covering explosive dust are included in:

- *CFR 29 1910.307*
  Hazardous (classified) locations
- *CFR 29 1910.1200*
  Hazard communication
- *CFR 29 1910.269*
  Electric power generation, transmission and distribution
- *CFR 29 1910.272*
  Grain handling facilities

To quell hazardous dust accumulation, a dust control system has to meet the *National Fire Protection Administration (NFPA) 654, Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*. According to the NFPA's website:

> This standard shall apply to all phases of the manufacturing, processing, blending, conveying, repackaging, and handling of combustible particulate solids or hybrid mixtures, regardless of concentration or particle size, where the materials present a fire or explosion hazard.

Topics include facility and systems design and construction, identification of combustible dust flash fire or explosion hazard areas, process equipment protection, fugitive dust control and housekeeping, ignition source identification and control, fire protection, training and procedures, and inspection and maintenance. *(From the description of NFPA 654 on NFPA.org website.)*

OSHA has listed revised regulations for exposure to silica dust among its 2015 Regulatory Priorities. The agency's proposal is to "half and harmonize" silica exposure thresholds, reducing the permissible level and making it consistent in all industries. The Mine Safety and Health Administration (MSHA) has vowed to accept the revised silica standards when issued. Affected industries—including various mining, aggregate, and construction industries, are, in general, opposed to the new rules.

In the United States, MSHA regulations in *30 CFR Section 56.5001* set forth the exposure limits for airborne contaminants for surface metal and non-metal mines, while *57.5001* sets forth the exposure limits for airborne contaminants for underground metal and non-metal mines. Both sections state:

> ... The exposure to airborne contaminants shall not exceed, on the basis of a time weighted average, the threshold limit values adopted by the American Conference of Governmental Industrial Hygienists, as set forth and explained in the 1973 edition of the Conference's publication, entitled "TLV's Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1973," pages 1 through 54, which are hereby incorporated by reference and made a part hereof.

Controlling Conveyor Dust

Because they handle large quantities of material through various terrain and environmental conditions, bulk-materials-handling belt conveyors are likely to generate significant quantities of dust. (**Figure 17.6.**)

As NIOSH's *Dust Control Handbook for Industrial Minerals Mining and Processing* notes, "Another challenge particular to conveyors is their ability to generate or liberate dust whether they are loaded heavily with ore or nearly empty."

With any conveyor system, the following information is needed to select which dust-control system is better for any application:

- **Concentration** – Amount of dust and particle size.
- **Characteristics of the Dust** – Abrasiveness, hygroscopic, combustible, density.
- **Characteristics of the Air Stream** – Temperature, moisture content, vapor, total air volume, air speed.
- **Efficiency** – Degree of collection efficiency required.
- **Disposal** – What will happen to the collected/suppressed dust.

There are several ways to manage the creation and escape of conveyor dust, or indeed dust in general.

1) Reduction (Control the creation of dust and prevent its suspension in the air.)
2) Containment (Confine the dust to prevent its escape and promote its return to the main body of material.)
3) Suppression (Remove with water spray.)
4) Collection (Remove via filtration.)

Figure 17.6.

As they move large amounts of bulk materials, belt conveyors are likely to release large amounts of dust.

Figure 17.7.

Improving containment at transfer points is one way to reduce the escape of conveyor dust.

While these are all identifiable and distinct methods of dust management, in many instances they can and should be combined to produce more effective dust control.

Dust Reduction

Dust reduction is the minimization of the amount of dust created through a redesign of the process or of the equipment. Measures to accomplish the minimization of conveyor dust include:

- Alteration of material sizes
- Control of belt speeds
- Management of impact
- Reduction of drop heights
- Control of air movement

These techniques will reduce the amount of dust created, and hence the amount of dust available to escape. As an example, the use of chutes with engineered material-flow will both reduce impact levels and control air flow, thus reducing the creation and expulsion of dust.

Dust Containment

A second step in dust management is containment; that is, the keeping of dust within the conveyor system. This step involves the reduction of the escape of airborne dust by reducing the amount and velocity of air entering into the conveyor system and reducing the holes through which dust-laden air can escape. (**Figure 17.7.**)

The closing of holes includes the filling of bolt holes and the closing of access doors and observation ports. Material is also contained through the use of expanded skirtboard 'stilling' or 'settling' zones and various passive dust-control measures including belt-edge seals, dust curtains, and conveyor tail-gate seals.

Passive filtration methods, including the use of dust bags—which allow exiting air to pass through a filter media prior to escaping—can be included in this method.

Dust Suppression

The addition of moisture to reduce the escape of airborne particles is called dust suppression. The moisture can be supplied as water or as chemically enhanced water. (**Figure 17.8.**)

The simplest method to add moisture to the body or stream of a conveyed material stream is to apply water while the material is in freefall, as in moving from the discharge of one conveyor to the loading zone of a second conveyor. This allows the water to make contact with as much of the material as possible.

The addition of water to the material can have harmful effects to the material's flow and handling, such as screen blinding, chute plugging, and increased carryback. Water can impact all of the properties of any bulk material, including its performance in the process.

Ideally, water should be added to produce a moisture content that is near or slightly more than the amount needed to prevent dust from being generated. The proper amount of water required is based on the material properties and will vary from application to application. Chemical additives can improve effectiveness, while minimizing the rate of water addition.

Foam-based dust suppression is another method to improve dust control while using less water. Foam systems apply a surfactant, but also use compressed air to expand the mixture, further increasing efficiency per volume of water added.

When adding chemically enhanced water in spray or foam, care must be taken not to introduce contaminants into the material.

Figure 17.8.

Dust suppression is the application of water or water enhanced with additives to control dust.

2

NIOSH Dust Control Handbooks

A useful collection of information on dust and dust management systems is presented in the *Dust Control Handbook for Industrial Minerals Mining and Processing.*

The 314-page handbook was published in 2012 by the U.S. National Institute for Occupational Safety and Health (NIOSH) in conjunction with the trade association Industrial Minerals Association-North America.

The Table of Contents in NIOSH's Industrial Minerals Handbook details the publication's contents:

1. Fundamentals of Dust Collection
2. Wet Spray Systems
3. Drilling and Blasting
4. Crushing, Milling, and Screening
5. Conveying and Transport
6. Bagging
7. Bulk Loading
8. Controls and Secondary Sources
9. Operator Booths, Control Rooms, and Closed Cabs
10. Haul Roads, Stockpiles, and Open Areas

While the entire *NIOSH Industrial Minerals Handbook* contains useful and interesting information, Chapter 5 Conveying and Transport (on pages 133 to 154), is particularly relevant to the discussions in this volume.

The *NIOSH Industrial Minerals Handbook* follows up on *NIOSH's* earlier guidebooks *Best Practices for Dust Control in Metal/Nonmetal Mining* and *Best Practices for Dust Control in Coal Mining*, both released in 2010.

All three handbooks are available for free download at the NIOSH website: *www.cdc.gov/niosh*. All three publications are in the public domain and may be freely copied or reprinted.

Another method to suppress dust with water is with fogging. This technique for dust control consists of placing a water fog of very fine droplets into the airstream. Dust particles will meet and bond with the water droplets, and the now heavier particles will fall out of the airstream.

The water drops must be of similar size to the dust particles for bonding to take place. Creating droplets of the proper size can be accomplished by passing high-pressure water through atomizing nozzles. Droplet sizing can also be accomplished by combining low-pressure water with air. Passing the water through special 'two fluid' nozzles with the air will atomize the water into the size of droplet desired.

Dust Collection

Collection is the act of mechanically gathering the dust-laden air in the transfer point and pulling this air through a filter. In the filtration process, the individual dust particles are agglomerated, harvested on the filter media. The agglomerated material can be pulled into one place, called central collection. It can also be filtered and redeposited at the various places in the conveyor system or the industrial process; this is termed unit filtration. The unit systems can be installed to return material to small collection points or return it to the point where it was collected. (**Figure 17.9.**)

Material properties and the system 'footprint'—that is, the space and utilities required—must be considered when a dust collection method is selected.

Housekeeping and Maintenance for Dust Control

Key ingredients in any dust-control plan are the providing of adequate housekeeping and maintenance.

A common violation reported during inspections involves 'hazardous levels of dust accumulation in the workplaces due to poor housekeeping practices.' The NFPA defines hazardous surface dust as any dust layer of $^{1}/_{32}$ in. [≈0.8 mm] or greater. This has been referred to as the 'Paper Clip Rule,' as it is concerned with any accumulation of dust thicker than the wire used in the standard paper clip.

Even diligent cleanup of floors and work surfaces is not enough if more elevated areas are neglected. Dust accumulation on rafters and overhead surfaces or on top of machinery is a frequent culprit in leading to explosions. (**Figure 17.10.**)

NIOSH's Dust Control Handbook for Industrial Minerals Mining and Processing noted:

> Controlling dust from conveyors requires a constant vigilance by the maintenance staff to repair and replace worn and broken parts, including conveyor belting. Basic maintenance and inspection are required to ensure that all parts of the system are performing to their capacity. Material can escape through chutes worn from rust or abrasion, and even small holes created by missing bolts or larger holes created

Figure 17.9.

Small air cleaners can be installed above conveyors and transfer points to reduce airborne dust.

Figure 17.10.

The accumulation of dust that escaped from conveyors can lead to explosion hazards and equipment problems.

from open access doors can be a pathway for fugitive dust.

When it comes to the dust collector, an important housekeeping requirement is to change filters when airflow through the system reaches the differential pressure limit as prescribed by the manufacturer. This pressure drop across the collector negatively affects the ability of the dust collection system to capture the dust.

BEST PRACTICES

Best practices for dust management around belt conveyors (**Figure 17.11.**) include:

- Conduct a hazard analysis to assess risk and determine the appropriate methods of dust control. The first step in this analysis is determining if the dust is explosive.
- Design and operate conveyor systems in ways to minimize the creation of dust and to prevent the escape of dust that cannot be prevented.
- Enclose the system, control the air flow, utilize passive measures—where possible—reduce air flow, and capture airborne dust.
- Apply dust-suppression and/or dust-collection technologies where compatible with conveyed material, process, and budget.
- Provide appropriate maintenance for the dust management systems—containment, collection, and suppression—to assure good working order and proper efficiency.
- Apply appropriate housekeeping to minimize accumulations of fugitive material that can interfere with productivity, equipment life, safety, and employee health.
- Achieve regulatory limitations to preserve the respiratory health of those who must work on or around conveyors in dusty conditions.

CLOSING THOUGHTS
Considering Dust and Dust-Control Systems

Controlling conveyor dust is a key to improving the health and productivity of those who work around belt conveyors handling bulk materials (**Figure 17.12.**) The use of personal protective equipment (PPE) may be vital, but it should never be the last resort of protection.

Figure 17.11.

The application of best practices for dust control around belt conveyors (as shown on the right) will help reduce the escape of fugitive material.

Personal protective equipment should not be a substitute for proper dust control and should be used only where dust control methods are inadequate or ineffective.

Figure 17.12.

Control measures can reduce the large amounts of air borne dust that rise from the handling of high volumes of bulk materials on belt conveyors.

Just as the types of dust are numerous, the methodologies to control that dust are numerous. A facility must carefully consider the proper method to ensure success. Solutions should be evaluated based on the requirements of the facility and the conveyed material, as well as the circumstances of—and power sources available at—the installation point.

A proper dust-control solution is critical in preventing these problems, and can keep a facility—and its employees—safe, healthy, productive, and profitable. ⚠

2

Chapter 18 Access

Note:
Some of the material in this chapter has been adapted from Chapter 26 Access in Martin Engineering's book, *FOUNDATIONS™ The Practical Resource for Cleaner, Safer, More Productive Dust & Material Control, Fourth Edition*.
For more information, visit martin-eng.com/foundations.

INTRODUCTION
Avoiding Pain in the Access

Access can be defined as the 'right and ability to enter or use.' In a bulk-materials-handling system, access is used to mean observation points, entry doors, and workspace for repairs and cleaning. (**Figure 18.1.**)

To maintenance and operations personnel, proper access is critical to productivity. (**See Better Access for Maintenance Improves System Availability.**) This means safe, quick, and easy access to a problem should outweigh concerns such as cost. It has been estimated that providing proper access in the design of a bulk-materials-handling system can account for as much as 15 percent of the capital cost of a project.

Yet, when a conveyor system is being designed, there is rarely enough money allocated to do more than provide the minimum access required by code. This practice results not only in lost production time and increased time required for maintenance, but also in increased safety and health costs. From the perspectives of ownership and management, inadequate access contributes to continuing problems with lost productivity and unnecessarily high maintenance costs. Lack of proper access leads to poor maintenance practices; poor maintenance often leads to emergency outages, which in turn affect the operation's productivity and profitability.

Insufficient access to equipment results in lost productivity and dirty systems, due to the difficulty of cleaning and making required repairs. It has been estimated that poor access could add as much as 65 percent to the maintenance and cleaning costs of a bulk-materials-handling system over its lifetime.

Of course, adding proper access later—after the materials-handling system has been completed and the access mechanisms have been found wanting—will cost substantially more, if it is even possible to accomplish.

For conveyors there are two general categories of access that need to be considered. The first is for local or immediate access to a specific piece of equipment—such as an idler or belt cleaner—to allow inspection and maintenance. The second is for general access along a conveyor or into a transfer chute, such as fixed steps, ladders, and walkways.

Access: Making it Easy

It is frustrating to maintenance personnel when they cannot work on equipment—equipment that would require minimal time to repair—because they cannot gain safe and proper access to it. Delays in access may be due to a requirement for a confined-space permit, for air testing, for scaffolding or man lifts, for cranes or hoists, or for special tools required to open access doors. In some cases, it is necessary to remove the entire system just to gain access to the component requiring service attention. These delays can be mitigated through the design of proper access, and by staging tools and parts close to the required location.

Three easily achieved goals should be included when designing proper access into a materials-handling system:

A. Easy to see

   If equipment develops a problem that cannot be seen by plant personnel, the problem tends to grow unseen into a catastrophic situation.

B. Easy to reach

   If a piece of equipment develops a problem, but the equipment is difficult for maintenance personnel to reach, repair is likely to be postponed, again risking a catastrophic situation.

C. Easy to replace

   If an equipment problem is known, but unnecessarily requires an outage to correct, the broken equipment is likely to remain out of order for an extended period.

When systems are too difficult to see, reach, and replace, plant operations or maintenance personnel may attempt shortcuts during repairs. Such shortcuts often increase risks to safety, as well as add the potential for additional damage to equipment. Taking shortcuts—whether intentionally or because of the lack of proper access, and therefore, the inability to follow proper maintenance procedures—can easily result in reduced safety, shorter equipment life, reduced process efficiency, and an increase in the emission of fugitive materials.

Figure 18.1.

The word 'access' is used to mean observation points, entry doors, and workspace for repairs or cleaning.

Better Access for Maintenance Improves System Availability

Proper access is critical for safe and effective operation and maintenance.

It is commonly accepted in the United States industry that, in a typical operation, as much as 30 percent of a maintenance worker's time is spent simply accessing the equipment to be serviced, and only 25 percent of maintenance time is actually spent on 'wrench time,' that is, actually maintaining equipment. The rest of the time is spent searching for information and traveling to the equipment to be maintained. Access plays a critical role in improved equipment availability and maintenance budgets.

Availability can be calculated in two ways. The first is to set as 100 percent the amount of time required to produce whatever production level (or amount of materials) was planned for the year. A second method is to set at 100 percent as operations at all times—for example, all the hours the plant is open, and all the time the plant has production personnel in place—and then calculate the time the system is actually able to operate.

In operations where the goal for system availability is set at 90 percent, 95 percent, or even higher, any time lost because of the delay in a worker's ability to reach or access the equipment in need of service is a needless drain on operational efficiency. To improve availability, the time required to access the equipment must be reduced.

Availability can be calculated as:

$$\text{Availabilty (A)} = \frac{\text{Mean Time Between Failure (MTBF)} - \text{Mean Time to Repair (MTTR)}}{\text{Mean Time Between Failure (MTBF)}}$$

The figure for Mean Time to Repair (MTTR) includes the time required to access the equipment, and so any increase in time to access leads, in turn, to greater MTTR and a corresponding reduction in Availability.

To provide an example, assume a typical set of belt cleaner blades lasts 1,000 hours Mean Time Between Failure (MTBF) and requires an average of 3 hours (MTTR) for replacement—these figures are based on a 2015 survey of Martin Engineering Service Technicians. This 3-hour replacement time includes the 30 percent time loss for access, or 0.9 hours.

If the access time could be eliminated by design, the difference in Availability for the belt cleaner would be one tenth of one percent.

$$A_{3h} = \frac{1000 - 3}{1000} = 99.7\% \text{ vs. } A_{2.1h} = \frac{1000 - 2.1}{1000} = 99.8\%$$

If downtime costs $100,000 per hour and cleaners are serviced only on an emergency basis, the cost of access each time the cleaner is serviced is: $100,000 x (99.8% - 99.7%) = $100.

If the belt cleaner could be safely serviced while the belt is running (thus requiring no outage), Conveyor Availability is 100% and the savings in time is 3 hours x $100,000 = $300,000.

There is no positive effect on the operation's bottom line when Availability is 100%, as there have been no production hours added. The true saving from 'designing for access' and allowing cleaner service while the belt is running can be calculated as 0.9 hours multiplied by the crew's hourly rate; at $75 per hour overhead each for a two-man crew the savings would be $135.

The savings are less significant, and less tangible, because no maintenance jobs have been eliminated—no workers have been laid off—but their productivity has been improved. This may allow the plant to avoid the need to hire additional maintenance personnel or avoid hiring outside contractors.

These calculations are true if the cleaner is serviced on a timely schedule. Unfortunately, experience tells us that when cleaners are serviced during planned outages, they are often the lowest priority on the maintenance list and, as a result, service is often delayed until the next scheduled outage. Cleaner service is thus neglected, and the end result is an increase in fugitive material that then increases other conveyor maintenance and cleaning problems.

To improve a bulk-handling conveyor's availability—that is, the time the system is actually able to operate—the time required to reach the equipment must be reduced. That is why it is critical to make conveyor access safer and easier, and to develop components such as cleaners that are service-friendly.

The Need for Observation

Access systems, including doors and work platforms, should be installed to make it easy to reach and observe equipment. Flow problems within chutes may be more easily solved if the material path can be observed. The actual path of material within a chute cannot always be predicted, so observation is necessary to allow adjustment of diverters, gates, and grizzly bars. (**Figure 18.2.**)

Many transfer chutes have only one inspection door. This is usually installed near the head pulley, where it does not permit a view of the actual material path in the lower transfer chute and skirted area where problems often occur.

The chute should incorporate observation openings with easy-to-operate covers located away from the material path. These openings should allow safe observation of both the material flow and component wear at critical areas of the installation. The openings should be limited in size and/or protected with fixed bars or screens to prevent personnel from reaching in or material from flying out. (**Figure 18.3.)** Appropriate warning signs should warn workers of the dangers of opening the door while material is moving. (**Figure 18.4.**)

Access and Inspection Doors

In the words of the 7th edition of the Conveyor Equipment Manufacturers Association book, *Belt Conveyors for Bulk Materials* [*CEMA Book*]:

> Access doors that are strategically placed and sized will greatly reduce the difficulty of servicing equipment and thus lead to more frequent and effective maintenance.

However, the *CEMA Book* also points out some safety issues that result from the presence of access doors:

> Such access while the conveyor is in operation may create serious safety hazards. Hazards that workers may be exposed to include flying or falling material and moving machinery. Often access doors lead to confined spaces and proper precautions are needed before entering a confined space.

Recommendations for access doors found in the *CEMA Book* are:

- Access doors should be sized and placed on enclosures in locations that facilitate easy service of equipment.
- Warning labels are to be placed in a conspicuous location near or on the access door.
- Access doors should be interlocked with the conveyor drive to prevent injuries

Figure 18.2.

For safety, doors into conveyor chutes should be well away from the material flow path.

Figure 18.3.

Doors can be screened to prevent material flying out or workers reaching into the enclosure.

Figure 18.4.

Appropriate warning stickers should be placed to warn of the danger of opening a door when material is moving.

when known potential hazards exist inside the enclosures.

- Access doors should be provided with screens to prevent accidental contact when hazards exist.

Inspection and access doors should be side opening and sized so personnel can easily and safely view the components inside the structure. Doors must be installed on the non-wearing side(s) of a chute—that is, the side(s) away from the flow of impacting or abrasive material.

Doors should be designed for easy operation in tight clearances, with corrosion-resistant hinges and latching systems. It is important that all ports be dust-tight through use of a securely sealing door. Hinged metal doors with easy-opening latches are now available to provide access. (**Figure 18.5.**) Flexible rubber 'snap-on' doors provide a dust-tight closure, while allowing simple, no-tool opening and closing, even in locations with limited clearances.

Poorly designed doors may have hinges and latches that are difficult to operate and, as a result, may impede access. In addition, door seals unable to withstand abrasion and abuse from materials and implements—used to reach through the doors—may leak and become sources of dust. Some access doors also have small ledges or flat shelf areas, where combustibles such as coal might accumulate, creating the risk of fire and explosion.

Door sizes should be large enough to provide the required access. If the observation and service requirements are limited to systems such as belt cleaners, a 225 × 300 millimeters [≈9 × 12 in.] or 300 × 350 millimeters [≈12 × 14 in.] door is usually sufficient. If service to major components, such as chute liners, will be necessary—or if personnel will need to use the door as an entry into the structure—then door sizes of 450 × 600 millimeters [≈18 × 24 in.], or 600 × 600 millimeters [≈24 × 24 in.], or larger will be necessary.

When there is a possibility of contact with moving machinery or flying materials behind the access door, the door should be locked or interlocked with the conveyor drive. Otherwise, the door can be equipped with a screen that allows inspection without the risk of injury from flying material hazards, or from workers reaching in through the opening. (**Figure 18.6.**)

It is also essential that access doors and covers be closed following use, to avoid the escape of material and the risk of injury to unsuspecting personnel. Doors should be easy to close securely, once the maintenance procedure is finished.

It makes sense to locate the attachment points for safety harnesses in line with the access doors.

Space Around Conveyor Systems

In order to save costs, conveyor equipment is often placed in small galleries or enclosures. (**Figure 18.7.**) One side of the conveyor is typically against a wall, an adjacent conveyor, or other equipment. It is extremely difficult to service this type of installation. If the conveyor is installed flush against a wall, vessel, or other structure, basic service requirements—such

Figure 18.5.

Hinged metal doors with easy-to-open latches are one option for providing access to enclosures.

Figure 18.6.

A screen installed behind the door can keep lumps of material from flying out when a door is opened.

as bearing lubrication or idler replacement—become major operations requiring extended production outages.

Generally, there must be sufficient room to allow access to all sections of the conveyor system, and in particular, both sides of the conveyor. Failure to provide access to both sides of the conveyor is the most common deficiency in making conveyors maintainable.

The open space along the most critical side of a conveyor should be at least the width of the conveyor belt, with a minimum of 750 millimeters [≈30 in.]. The other side of the conveyor should have space equal to at least one-half the width of the belt, with a minimum of 600 millimeters [≈24 in.] space along the entire length. This two-sided access facilitates replacement of equipment, such as idlers, that cannot be easily handled by one worker.

The *CEMA Book* includes detailed specifications for access requirements around conveyors in its Chapter 2 Design Considerations.

Overcoming the Encroachment of Other Systems

A common problem is the encroachment of piping, conduit, and other equipment installed too close to the conveyor and in manners that impede the access to belt conveyor components.

It is not uncommon to see a conveyor or transfer point captured in a web of electrical conduit, dust-suppression piping, control panels, or sprinkler systems. Any attempt to reach the components of the conveyor must first get past the 'thicket' of piping. The interference created by these other systems results in a variety of complications to the operations of the plant.

Figure 18.8 shows a transfer point buried in conduit making maintenance access of this side of the transfer point almost impossible.

It is common practice to 'abandon in place' damaged cables rather than remove them.

Figure 18.9 shows a cable tray following a conveyor path at ground level, when to the immediate right there is an elevated structure for support of cableways and piping. Not only does this cable tray obstruct maintenance access, it encourages maintenance personnel to walk on the cable tray when accessing return rollers on this side of the conveyor.

Figure 18.7.

Conveyors are often placed in small enclosures or galleries, making service and cleaning chores more difficult.

Figure 18.8.

A thicket of conduit will make any maintenance activity at this conveyor transfer point more difficult.

Figure 18.9.

A cable tray installed beside this conveyor obstructs service access to the conveyor.

Figure 18.10.

A cableway is mounted on the outside of this conveyor structure, allowing electrical components to be connected through flexible cables.

In contrast, **Figure 18.10** shows how the cableway can be mounted on the outside of the walkway with flexible cables routed to the electrical components.

Figure 18.11 shows a typical height of the conveyor off the ground according to the common minimum code requirement of the belt which is 300 millimeters [≈12 in.] from the return roller to the ground, as noted in section 2.3.3 of *AS/NZS 4024.3611:2015 Safety of machinery – Conveyors – Belt conveyors for bulk materials handling*. The presence of conduit makes cleaning under this conveyor difficult and the low clearance between the surface and return rollers practically guarantees the need for frequent cleaning.

Figure 18.11.

The presence of conduit along the underside of this conveyor will make the removal of fugitive material more difficult.

Figure 18.12.

This conveyor features walkways on both sides, but guarding and piping obstruct the already narrow passages.

Figure 18.12 shows a conveyor with walkways on both sides but with equipment guarding and piping obstructing a clear minimum passage.

To control the growth of these auxiliary systems around the conveyor, the designer should specify the equipment to which maintenance access is necessary. By identifying specific areas in the conveyor plans for the installation of control panels, gate actuators, plumbing and conduit lines, and other equipment, unnecessary obstacles can be avoided and easy access maintained.

Beside the Conveyor

Proper access requires the provision of walkways and work platforms beside conveyors. These should provide a firm path adjacent to the conveyor and around head and tail pulleys with easy access to all points where observation, lubrication, or other maintenance chores are required.

Walkways should be a minimum of 750 millimeters [≈30 in.] wide for passage, and 900 millimeters [≈36 in.] wide in areas where service work must be performed. Both areas should have ample headroom; anywhere a person must stand or kneel to perform service or inspection, the 'overhead' or 'head room' should be at least 1,200 millimeters [≈48 in.] Areas where frequent service or cleaning is required should have solid flooring rather than an open grate.

When conveyors run parallel to each other, the space between them should be a minimum of 750 millimeters [≈30 in.] or the width of the belt—whichever is greater—to allow for belt repair and removal of idlers.

Another common deficiency in conveyor access design is failure to allow adequate space for cleanup. A study of conveyor-related accidents in mining showed that one-third of all accidents occurred to workers trying to clean under, or around, the carrying and return runs of the conveyor. Areas that require frequent cleanup should allow for mechanical cleaning, such as the use of a skid-steer loader or vacuum truck under the conveyor. If this is not practical, a minimum clearance of 600 millimeters [≈24 in.] between the bottom of the return rollers and the floor should be provided.

Access Requirements Around Equipment

The minimum access around equipment is the area necessary to accommodate the largest piece of equipment. This is determined by measuring the largest item and adding 450 to 600 millimeters [≈18 to 24 in.]. There should also be access on both sides of the structure, with a minimum of 900 millimeters [≈36 in.] clearance on the second, non-critical side, with a clear path to a lifting area for removal of the equipment. A convenient staging area for large replacement parts is a good idea.

Access for Belt Repair and Replacement

Access for belt maintenance requires an area convenient for lifting or lowering the vulcanizing equipment and exposing the conveyor belt itself. Removal of conveyor covers, load-zone skirtboards, wear liners, and chute wall will add significant time to the process. Suitably designed lifting lugs or points should be provided in the original design. At least 900 millimeters [≈36 in.] plus the width of the belt is required on each side of the conveyor. In addition, a distance of three meters [≈10 ft] long where the belt is exposed—that is, not enclosed—is required to facilitate repair operations.

Access at the Takeup

Maintenance and repair of a gravity takeup system may be dangerous and time-consuming. Two chain fall hoists of sufficient capacity to raise and lower the counterweight are typically required. Because many of these takeup systems are close to the head pulley, the maintenance access area on inclined conveyors may be elevated. Access platforms that provide adequate space for maintenance of bearings and pulleys and for rigging chain fall hoists are essential. A lifting mechanism that can remove the force of the gravity takeup counterweight from the belt might save many man-hours during conveyor repair.

Sometimes, an obstruction exists in the walkway. This might be a support beam or a protrusion from a piece of equipment. A worker will then need to decide which side of the obstruction to cross. It is always a good idea to cross the obstacle so the obstacle is between the worker and the conveyor belt. If footing or balance is lost, a worker would be better served to fall into the obstacle than into a moving conveyor.

Walkways and Work Platforms

Belt conveyors are pieces of industrial equipment that may be elevated. As such, they are governed by the rules of elevated platforms. If a part of the conveyor needs maintenance, a ladder or walkway is usually installed to give workers access. If a walkway is constructed, there are rules regarding the width of the walkway and the height of the rails attached to it.

Proper design should include sufficient space on each side of the conveyor for safe maintenance activities and for the safe removal of spilled material.

Many standards require only walkway access along one side of the conveyor, and then only a minimum width of 24 inches [≈600 mm], as seen in *AS/NZS 4024.3610:2015 Safety of machinery – Conveyors – General requirements* section 2.4.2.4. The *CEMA Book* offers Table 2.28 Minimum recommended clearances and access requirements, which recommends the dimensions include a minimum of 30 inches [≈750 mm] on what is termed the "Primary side" and 24 inches [≈600 mm] for service access on the "Secondary side."

In the United States, the Occupational Health and Safety Administration (OSHA) regulations in *29 CFR Section 1910.23* give very thorough guidance to the construction of walkways and rails. For example, any elevated platform over 4 feet [≈1,220 mm] above the surrounding surface must be guarded with a standard railing. The rails must be located 42 inches [≈1,067 mm] and 21 inches [≈533 mm] from the top of the top rail to the walking surface. The rails must have toe boards. The rails must be constructed in such a way that they can withstand a load of 200 pounds [≈890 N] in any direction and at any point upon the top rail.

Conveyor specifications often require a coefficient of friction of a minimum of 0.5 for walkways whether on a hard surface, ramps, or elevated walkways. Defining and measuring this coefficient of friction has been a source of controversy. As a result, OSHA in the United States has recently required walkways to have a wet static coefficient of friction of 0.60 or greater, or a wet dynamic coefficient of friction of 0.42 or greater. These scores are classified as "High-Traction" under the testing procedures specified in the American National Standards Institute/National Floor Safety Institute (ANSI/NFSI) *B101.1* and *ANSI/NFSI B101.3* standards respectively.

Figure 18.13.

A gap in this catwalk was covered with a piece of plywood, which then became a trip or fall hazard in itself.

Elevated walkways should have open grating or mesh that reduces the propensity for spilled materials to accumulate. However, this open mesh may still require cleaning. (**See Corroded Walkway Leads to Serious Injury.**) **Figure 18.13** shows a catwalk with a trip hazard and an attempt to cover the gap with a piece of plywood that has broken and also become a trip hazard.

Minimum headroom for walkways alongside conveyors should be at least 2 meters [≈79 in.] on the main travelway, as specified in section 2.4.2.4 of *AS/NZS 4024.3610:2015*.

Tunnels should not have the conveyor positioned against one wall and should have at least two ways of escape available for workers trapped inside. Appendix D in the Australian/New Zealand conveyor standard *AS/NZS 4024.3610* notes that in the design of tunnels, galleries, and other confined areas, enough space should be provided on at least one side of the conveyor to allow the passage of a patient being carried on a stretcher.

Walkways on both sides of the conveyor are often placed on structural extensions from

Corroded Walkway Leads to Serious Injury

In August 2015, the United States Mines Safety and Health Administration (MSHA) issued a report about a serious injury accident. The report described how a miner at a surface crushed limestone facility "was seriously injured when the expanded metal walkway he was standing on suddenly failed." As a result, the worker fell 10 feet [≈3 m] to the ground below and suffered serious non-fatal injuries.

According to the MSHA document, "The expanded metal walkway was covered with conveyor belt to aid in shoveling spillage." This layer of belting "allowed corrosive material to accumulate and accelerated the deterioration of the expanded metal" walkway. The report further noted, "The application of the conveyor belt masked the signs of deterioration on the walkway, making a thorough workplace examination difficult."

The MSHA report offered the following guidelines for walkway safety:

- Examine your work places for all possible hazards and correct them before you perform work.
- Conduct structural inspections periodically.
- Look, listen & feel for abnormalities in walkways.
- Routinely examine metal structures for indications of weakened structural soundness (corrosion, fatigue cracks, bent/buckling beams, braces or columns, loose/missing connectors, broken welds, etc.).
- Keep corrosive material spillage/build-up removed from metal structures.
- Report all areas where indications of structural weakness are found.

the bottom of conveyor trusses. This practice places the return idlers below the walkway, and thus makes inspection and replacement more difficult and more dangerous than necessary. It might be useful to construct the walkway below the return idlers, provide a mobile work platform, or use ground surfaces and clearances suitable for the operation of a man lift or bucket truck.

To eliminate an extended walkway, mobile maintenance platforms are sometimes used on long overland or elevated conveyors. (**Figure 18.14.**) This will reduce the cost of the structure, and also will allow service where the terrain makes access difficult. **Figure 18.15** shows a mobile maintenance trolley. **Figure 18.16** shows a hinged work platform with a caged ladder that can be swung into position for belt-cleaner maintenance.

While there are no specific rules about walkway safety, there are many safe practices that should be employed. The first and foremost is good housekeeping. Walkways around conveyors should be kept clear of any debris or spillage.

A conveyor is a powerful piece of industrial equipment, and great care must be taken when walking next to it. If there is material on a walkway, a worker may lose balance and fall into the conveyor. A concerted effort must be expended to prevent this type of event.

Ramps, Ladders, and Stairs

The dimensions for ladders and stairs have become standardized to help prevent trips, slips, and falls. The most common references are found in the International Building Code as published by the International Code Council.

United States standards are also presented in OSHA regulations in *29 CFR 1910.21 Subpart D – Walking-Working Surfaces* and in MSHA regulations in *30 CFR 56 Subpart J – Travelways*.

In general for conveyor access, ramps can be used at angles up to 20 degrees, and stairs with treads should be used for up to 50 degrees. Fixed ladders are used for greater angles.

Openings from walkways and work platforms to stairs generally do not require a barrier unless there is a safety hazard such as a moving landing. However, openings to a fixed ladder should always be provided with a barrier; common ladder barriers are a chain or a self-closing gate.

The dimensions and requirements for ramps, steps, fixed ladders, and work surfaces vary significantly from country to country; local regulations should always be followed.

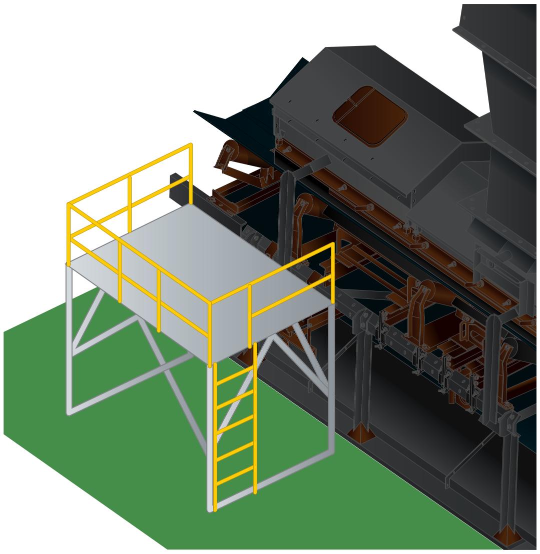


Figure 18.14.

Mobile maintenance platforms can be used to reduce costs and simplify access along long elevated conveyors.

Figure 18.15.

A maintenance trolley allows workers to move along a conveyor to perform service work where required.

Figure 18.16.

This cross-conveyor work platform is hinged, so it can swing into position for belt-cleaner maintenance.

Conveyors and Confined Space

Any discussion of access to equipment, whether for routine maintenance or emergency repair, should include the topic of confined space. In *29 CFR 1910.146*, the United States Department of Labor Occupational Safety and Health Administration defines "confined space" as an area that:

(1) Is large enough and so configured that an employee can bodily enter and perform assigned work; and

(2) Has limited or restricted means for entry or exit…; and

(3) Is not designed for continuous employee occupancy.

"Permit-required confined space"—shortened to "permit space" in common use—means a confined space that has one or more of the following characteristics:

(1) Contains or has a potential to contain a hazardous atmosphere;

(2) Contains a material that has the potential for engulfing an entrant;

(3) Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section; or

(4) Contains any other recognized serious safety or health hazard.

"Non-permit confined space" means a confined space that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious physical harm.

Figure 18.17.

The back wall of this chute is held in place with bolts on the side flanges, which allow the chute to be opened.

Permit-required confined spaces require cumbersome and costly safety procedures, including personnel training, safety harness and rigging, and added personnel for a 'buddy system.' Consequently, designing systems to minimize permit-required confined spaces may provide a significant return on investment. When maintenance and repair work can be done without requiring permits or specially trained personnel, the labor expense associated with such tasks is minimized.

Working in confined spaces requires special training, securing a permit for the job, and takes longer than work in unconfined spaces. Therefore, designing equipment for unconfined space service and adjustment is an important safety strategy.

Common cleaning or maintenance tasks that require confined-space entry are:

- Chute, skirtboard, and wear liner installation and replacement.
- Cleaning and unplugging of chutes.
- Belt cleaner installation and adjustment.
- Dust collector filter/bag replacement.

Improved systems that incorporate the following features of non-permit confined space are cost-effective over time.

- Easy access and sufficient access for entering and exiting the enclosure.
- Natural ventilation of the internal work areas.
- Materials that do not create a hazardous atmosphere.

The best time to reduce the amount of confined-space entry for installation and maintenance is during the specification and design stages of a project. Once the system is constructed and in operation, it is very difficult to redesign to eliminate confined space entry.

Another approach is to design non-confined space chute access that allows whole sections of chutes—especially those portions that see continuous abrasive wear—to be easily opened. (**Figure 18.17.**) This type of design allows repairs to be accomplished without requiring workers to be enclosed inside the chute. The same type of access can be designed for feeders, gates, silos, or bunkers.

Many manufacturers offer systems and products that can reduce the need for confined space entry. Examples would include:

- Chutes without liners made out of abrasion-resistant materials with modular designs for quick replacement.
- Chutes that hinge open and lay down for liner replacement.
- Skirtboards with external liners. (**Figure 18.18.**)
- Belt cleaners that can be withdrawn from the side of the chute for service without entry into the chute.
- Installation of flow aids like air cannons and vibrators to reduce buildup in chutes.
- Modular air cleaners for individual transfers rather than centralized dust collection.

REGULATIONS AND STANDARDS

Access to conveyors is covered in the walkway and other sections of the regulations specified by various issuing bodies. The following contains a sampling of the conveyor-specific regulations that can be applied, in addition to those already discussed in this chapter. As always, local codes should be identified and followed.

Australia

The Australian/New Zealand standard *AS/NZS 4024.3610:2015 Conveyors – General requirements* specifies the requirements for access in its section 2.4. These requirements note the conveyor design should accommodate the needs to access the system for operating the conveyor as well as performing service activities such as inspection and lubrication.

It notes that in particular, means of safe access will be provided where the inspection and maintenance tasks will need to be performed while the conveyor is operating.

For understanding access to the conveyor and its controls, the *AS/NZS 4024.3610:2015* standard refers readers to *AS 4024.1702 Safety of machinery – Human body measurements* and *AS 4024.1703 Safety of machinery – Principles for determining the dimensions required for access openings*. The standard also suggests that Parts 1 through 4 of *ISO 14122 Safety of Machinery – Permanent means of access* be used for machinery elements of conveyors, provided these requirements do not allow an increase in hazards.

The standard notes that the requirements of *AS 1657-2013 Fixed platforms, walkways, stairways and ladders – Design, construction and installation* will be followed where platforms, walkways, stairs, or ladders are needed.

The conveyor standard specifically notes in its clause 2.4.2.2 that access should be provided to allow routine operations and maintenance to be carried out from floors or platforms, rather than from stairs or ladders.

In addition, the standard notes that where it is a possibility that a worker could fall onto a conveyor, means shall be provided to prevent the injury. The standard then refers to its clause 2.10.5.4, which notes that an assessment is suggested to consider both the risks of a person falling on the belt, and what safety measures should be undertaken.

Figure 18.18.

Installed outside the skirtboard, an external wear liner allows inspection and adjustment and improves sealing without requiring entry of confined spaces.

2

In clause 2.4.2.4 Working Clearance, the *AS/NZS 4024.3610* standard notes that space between the conveyor cargo and any part of the conveyor system, equipment, or structure shall be sufficient to prevent inadvertent contact. The section requires that where worker access is required alongside an operating conveyor, clearance will be a minimum of 600 millimeters [≈24 in.]. Headroom will be a minimum of 2 meters [≈79 in.].

The Australian/New Zealand belt conveyors for bulk materials standard *AS/NZS 4024.3611:2015* offers instructions regarding the provision of walkways on belt conveyors in its section 2.4 Design for Operability and Maintainability. The standard requires in clause 2.4.1 that a walkway for access be furnished on at least one side of those conveyors, as well as be supplied in other areas where inspection or service activities will take place. The clause further notes that it is sound policy to provide a walkway on both sides where access is required more regularly than on a monthly basis. In the cases where walkway access is not provided, the conveyor designer should provide (and document) a system to allow safe operation and maintenance.

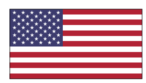
Canada

Regulations in *Health, Safety and Reclamation Code for Mines in British Columbia* specify the following:

> Walkways and Vehicle Curbs 4.1.11
>
> (1) Walkways shall not be less than 500 mm [≈20 in.] in width and shall be provided with safe access by stairways or fixed ladders.
>
> Conveyor Belts 4.4.16
>
> (3) Every conveyor way shall be provided with a walkway or other acceptable access for maintenance and inspection purposes.

In the province of Quebec, *Regulations respecting occupational health and safety in mines* has the following requirements:

> 373 Every conveyor shall …
>
> (3) be equipped with a footwalk and guardrail where it is installed more than 2 m (6.5 ft) above ground level or floor level, except where the conveyor can be accessed by means of an elevating platform or other mechanical means that complies with section 208 [where a worker is raised by means of the bucket of a loader] or 401 [where work in an open pit mine is performed from a list of acceptable equipment];
>
> (4) be equipped with a protective rail on the sides alongside which the workers move about.



United States

MSHA regulations in *30 CFR section 56/57.11001 Safe Access* and *30 CFR section 77.205(a) Travelways at surface installations* both state: “Safe means of access shall be provided and maintained to all working places.”

OSHA has regulations for walkways in *29 CFR 1910 Subpart D – Walking-Working Surfaces*. Applicable sections include *1910.22 General Requirements, 1910.23 Guarding floor and wall openings and holes*, and *1910.24 Fixed industrial stairs*.

ANSI A1264.1-2007 Safety Requirements for Workplace Walking/Working Surfaces and Their Access sets forth safety requirements for areas where danger exists of persons or objects falling through floor or wall openings, platforms, runways, ramps, and fixed stairs in normal, temporary, and emergency conditions.

BEST PRACTICES

CEMA published recommendations for passage and maintenance access clearances in Chapter 2 of the *CEMA Book*. The clearances are minimum fixed-width requirements for passage and clearances related to the belt width for the removal of components such as pulleys, idlers, and belt cleaners from one side.

In addition, CEMA recommends that piping and conduits be routed away from areas of the conveyor that require frequent access for maintenance or inspection.

To facilitate inspection and service, the conveyor will be fitted with walkways on both sides. These walkways will provide sufficient space for the required maintenance activities at points where service work will need to be performed.

Other Best Practices for conveyor access include:

- Follow guidelines for access in CEMA's *Belt Conveyors for Bulk Materials*. (**Figure 18.19.**)
- Elevate the conveyor a minimum of 4 feet [≈1.2 m] above the floor in the load zone and guard the return rolls so cleaning can be done under the conveyor when in operation.
- Start steps and walkways after the end of the load zone; use portable work platforms for maintenance.
- Interlock inspection doors with the conveyor drive when moving equipment can be accessed through the door opening or flying material hazards may be present.
- Use inspection screens on access doors that are not interlocked.
- Provide access to both sides of the conveyor for maintenance and cleaning or use mobile work trolleys or high lifts for elevated conveyors.
- When safe access cannot be provided on conveyor sections that are elevated more than 4 feet [≈1.2 m] above the floor, provide fall protection tie-offs at appropriate intervals and of sufficient load capacity.
- Follow local regulations for ramps, steps, walkways, and platforms.
- Design to eliminate the need for confined space entry.

CLOSING THOUGHTS
Covering Your Access

Most elevated conveyors purchased on price have walkways only one on side of the conveyor because the codes are vague or require access only on one side. This is another example of how the 'low bid system' reduces safety while 'meeting' the minimum code requirements. Some operators counter this risk with the preplanned use of man-lifts or mobile maintenance platforms.

Ladders and stairways are particularly susceptible to accumulations of fugitive material making their use less safe than it could and should be. Some operators replace ladders with a requirement for steps in order to reduce fall hazards due to fugitive material and from failure to guard the access to the top of the ladder. In general, allowing accumulations of fugitive materials reduces safety and increases the access time requirements for maintenance and cleaning procedures. Access to equipment for maintenance and repair is essential for a clean, safe, and productive system. Well-designed conveyor access need not be a trade-off between safety, accessibility, and cost. Safe access that is carefully located and adequately sized will increase dependability, reduce downtime—and the associated labor expense—required for maintenance, and minimize hazards such as dust and confined space entry. Over time, well-designed access improves safety and saves money. ⚠

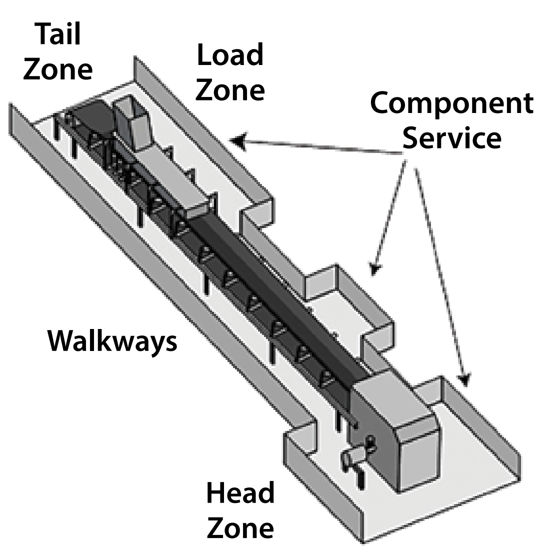


Figure 18.19.

The Guidelines for Access in CEMA's Belt Conveyors for Bulk Materials include recommendations for areas for component service as well as walkways, and areas in the tail, load, and head zones.

2

Chapter 19 Noise Hazards

INTRODUCTION
So What is All This Noise?

This chapter is concerned with noise—the sound waves in the air generated by bulk-materials-handling conveyors that can create health and safety issues.

Why is noise from belt conveyors an issue? Ideally, the belt moves smoothly and quietly over rolling components. But in reality, the sound of the system is vulnerable to influences such as friction between the belt and rollers, the clank of mechanical splices across the idlers, the crash of large quantities of heavy materials traveling through chutes and into loading zones, the resonance of hollow 'tin can' idler rolls, and the squeal of idler bearings degraded by fugitive material and/or lack of lubrication. Under the burden of these sound generators, the conveyor system can get loud enough to cause a noise problem for workers.

As S.C. Brown noted in a 2004 paper, *Conveyor Noise Specification and Control*:

> Large, outdoor belt conveyor systems for bulk materials are major sources of industrial noise and frequently become an environmental emissions issue for many existing and proposed plants.

Noise is associated with wasted energy, material degradation, and wear. Conveyor sound can also travel long distances through the ground and structures creating undesirable vibrations which can damage structures and shorten component life. Conveyor noise can reduce productivity and disturb neighbors, resulting in long-term health effects including irreversible hearing loss. Noise can also mask desirable sounds such as safety warning signals or verbal commands.

Conveyor noise can be useful. For example, an idler bearing producing an increased level of noise indicates an impending failure. Wise technicians can use these noises in their service planning and activities.

As Lawrence K. Nordell wrote in his 1998 paper, *Improving Belt Conveyor Efficiencies: Power, Strength and Life*:

> Engineers are now having to understand noise regulation in the design of the conveyor. Conveyors may pass through residential and farm areas, or residential areas may develop around planned conveyor routes. Operator safety and hearing impairment are also becoming regulation issues. Noise restriction is now becoming a line item in some conveyor design criteria.

The noise from a single roller may not be dangerous to workers, but the hundreds of rollers on a conveyor—most of the time combined with the sounds of other plant machinery—can add up to hazardous levels.

Fundamentals of Sound

Sound is perceived as pressure fluctuations causing our eardrums to vibrate. Loudness of a sound is an individual judgment that varies by person based on age, physical condition, and the distance from the sound and is not a scientific measurement. The potential for a sound to damage our hearing is proportional to its intensity, not its loudness. Thus, it is misleading to rely on a subjective perception of loudness as an indication of the risk to an individual's hearing. *Noisehelp.com* offers the table below. (**Figure 19.1.**)

Sound is recognized by humans in frequencies from about 20 to 20,000 Hertz (cycles per second or Hz) and at sound intensities from 0 to 140 decibels (dBA). As a reference, normal human speech is about 65 dBA in the frequency ranges of 85 to 180 Hz for men and from 165 to 255 Hz for women.

Noise from several sound sources combines to produce a sound level higher than that from any individual source. However, the dBA values are not directly added, as they are already logarithmic quantities. Two equally intense sound sources operating together produce a sound level that is 3 dBA louder than one source alone; 10 sources might produce a sound level 10 dBA higher than a single source. The 10 dBA louder sound will be sensed (heard) as a doubling of the original sound level.

Levels of sound pressure and levels of sound intensity decrease equally with the distance

2

Difference between Sound Intensity and Perceived Loudness

Sound Level	Sound Intensity (Power)	[Typical Human] Perceived Loudness
60 dBA	1x [base level]	1x [base level]
70 dBA	10x [times as powerful]	2x [times as loud]
80 dBA	100x [times as powerful]	4x [times as loud]

Figure 19.1.

An increase of ten decibels (dBA) will be perceived as a doubling of a sound's loudness.

Courtesy of noisehelp.com.

from the source, losing 6 dBA for each doubling of the distance from the source. At that distance, the sound pressure drops to a half and the sound intensity to a quarter of the initial value.

Sound radiates from its source as a spherical pressure wave. Often in the case of conveyors, the spherical sound wave is often blocked or reflected by the position of the conveyor relative to the surface and surrounding structures and equipment.

Terms Relating to Sound

Terminology in the fields of Acoustics (the science of mechanical waves) and Audiology-Acoustics (the science of hearing) can be confusing. Terms with different meanings are often used incorrectly and/or interchangeably. The terms used in this chapter include:

- **Decibel** A unit of measure of sound pressure that compresses a large range of numbers into a more meaningful scale, often abbreviated as dB. Hearing tests indicate that the lowest audible pressure is about 2 x 10^{-5} Pa (0 dB), while the sensation of pain is about 2 x 10^{2} Pa (140 dB). Generally, an increase of 10 dB is perceived as twice as loud.
- **dBA** The noise intensity scale abbreviation for decibels levels associated with the human range of hearing; this is sometimes shown as dB or dB(A).
- **Frequency** The number of sound vibrations per second. A sound at a single frequency is called a pure tone; for example 440 Hz is the musical note 'A.'
- **Intensity** A measure of the energy of the sound wave at a specified distance in a scale relative to human hearing reception.
- **Noise** Unwanted sound. Most noise is a combination of many frequencies and at various intensities.
- **Sound** A wave motion, which occurs when a sound source sets the nearest molecules into motion. The movement spreads to molecules farther away from the source. The speed of sound propagation in air is approximately 340 meters per second [≈1,140 ft/s].

Health and Safety Concerns

Noise pollution adversely affects the lives of millions of people. Noise-induced hearing loss is the most common and often discussed health effect, but research has shown that exposure to constant or high levels of noise can cause countless adverse health effects. Studies have shown that there are direct links between noise and health. Problems related to noise include stress-related illnesses, high blood pressure, speech interference, hearing loss, sleep disruption, and lost productivity. Exposure to hazardous noise can result in quickened pulse rates, increased blood pressure, narrowing of blood vessels, nervousness, sleeplessness, and fatigue, not to mention the very serious problems of noise-induced hearing loss.

Other than hearing loss, there are a whole host of physical and psychological effects following long-term exposure to sounds, even sounds below 85 dBA. There are proven psychological reactions—for example, anger, strain, or nervousness—and physical reactions—increases in blood pressure or in excretion of magnesium—which may give rise to long-term disorders.

In 1973, Alexander Cohen of the National Institute for Occupational Health and Safety (NIOSH) reported on these issues in a paper, *Industrial Noise and Medical, Absence, and Accident Record Data on Exposed Workers*. In Cohen's research, a study was conducted on the attendance and accident files of 500 workers situated in noisy plants (95 dBA or higher) and 500 workers in quieter plants (80 dBA or less). Comparing the records of those workers, it was found that the workers exposed to the higher levels of noise had a significantly greater rate of accidents, diagnosed medical problems, and absenteeism. The study did caution that there may have been other conditions, besides noise, responsible for these differences.

One way that noise can permanently damage a worker's hearing is by a single brief exposure to a high noise level. But hearing damage can also occur gradually at much lower levels of noise, if there is enough exposure over time. (**Figure 19.2.**) To protect hearing, limit exposure to moderately high noise levels and give workers a recovery period after any extended noise exposure.

Noise can interfere with the recognition of danger signals such as conveyor start-up alarms, and fire or weather sirens. If the worker has hearing loss or is wearing ear protection, the warning may not be heard, particularly if the worker has already suffered hearing loss. Warning signals are usually required to be 10 dBA louder than the surrounding noise levels.

Complex tasks such as maintenance can be made more difficult and dangerous because noise can interfere with communication. When the ambient noise intensity is in the range of 85 dBA, it is usually necessary—even at close range—to shout directly at a co-worker to be heard. If the co-worker has hearing loss, commands and verbal warnings may be misunderstood. The efficiency of completing a task can be affected by noise—especially for complex tasks requiring decision-making and judgment—so the same task can be more complex for lesser-trained personnel.

The Characteristics of Conveyor Noise

The measurement and prediction of sound intensity levels for conveyor systems is a task for a specialist. Many factors such as weather, topography, distance to neighbors, and level of maintenance contribute to the complexity of these determinations.

In his Beltcon 18 paper, *Overland Conveyor Noise: Engineering Tools for Noise Reduction*, Ben van Zyl explained:

> As a linear source, an overland conveyor generates and emits noise over its entire physical length. … Conveyors are line sources characterised by a noise level which declines at a slow rate with distance (- 3 dB compared to - 6 dB per doubling of distance for a point source). As a consequence, given a line source and a point source producing the same levels at source (e.g. 3 m [≈ 10 ft] distance), the line source will produce higher noise levels at large distances. For example, on conveyor systems noise levels in the proximity of a transfer station are usually considerably higher than the corresponding levels at the conveyor. Notwithstanding, conveyor noise (due to a slower rate of decay) will overtake transfer station noise and dominate at larger distances from the line.

Sound intensities for conveyor components are usually measured using a stationary sound meter at a standard distance, often one meter [≈39 in.]. Sound related to human activity around the conveyor is typically measured using a noise dosimeter, a specialized sound-level meter worn by a worker to measure the noise exposure of a person integrated over a period of time.

Studies done on conveyor systems have yielded a wide range of results, showing noise levels close to the conveyor as high as 100 dBA and at 300 meters as low as 35 dBA.

The paper, *Conveyor Noise Specification and Control*, by S.C. Brown reported:

> Measured Sound Power Levels of conventional belt conveyors range from 113 dBA to 119 dBA per 100 m [≈328 ft] for typical 10,000 TPH 5 m/s [≈980 fpm] coal conveyors.

Ben van Zyl reported, "Normally running 24 hours per day, conveyors are audible over large

Exposure to Noise and Hearing Damage

At 91 decibels, human ears can tolerate up to two hours of exposure.
At 100 decibels, damage can occur with 15 minutes of exposure.
At 112 decibels, damage can occur with only one minute of exposure.
At 140 decibels, immediate nerve damage can occur.

Figure 19.2.

As the sound level goes up, hearing will be damaged in shorter intervals of times.

Courtesy of noisehelp.com.

2

distances at night when ambient levels in rural areas are typically in the order of 35 dBA."

He also noted:

> Conveyor noise (sound power) is characteristically rich in low frequency content. … Due to lower propagation losses, low frequency sound prevails over longer distances compared to high frequencies.

Sources of Conveyor Noise

In *Conveyor Noise Specification and Control*, S.C. Brown summarized conveyor noise-generation mechanisms as follows:

- Idler Roll Bearing Noise
- Idler Roll Shell Noise
- Belt Idler Interaction
- Air Pumping, Belt/Idler Roll
- Structure-borne Noise – conveyor support structure

Conveyor noise is usually attributed to the drive system, structure, chutes, idler construction, and the interaction between the belt and the idlers. The noise from the drive system can be considered a point source where other noise from the conveyor is distributed and can vary along its length.

Belt speed and loading affect the conveyor's noise generation with faster belts generating more noise from the idler surface and imbalance. In some cases, the interaction between the belt covers and the idler creates a sound similar to adhesive tape being removed from a surface.

Idlers are another source of conveyor noise, with roll surface, roundness, and balance being significant factors in noise generation. Research indicates that the rate of change of the surface of the idler—called Maximum Indicator Slope (MIS)—is the dominant noise-generation factor.

Another factor, Total Indicator Run-out (TIR) has been identified as a secondary factor in conveyor idler noise. TIR is a measure of the total 'out of roundness' of the roller, by measuring the maximum radius versus the minimum radius of the roller.

In its conclusion, the Beltcon 16 paper, *The Influence of 'Maximum Indicated Slope' and 'Total Indicated Run-Out' on the Noise Caused by the Interaction of Conveyor Idlers Rolls and Conveyor Belts*, by Paul Munzenberger and Craig Wheeler noted:

> The results shown indicate the MIS of a conveyor idler roll is the dominant cause of the noise produced by the interaction of a conveyor idler roll and the conveyor belt that is in contact with it.

The enclosed steel tube of conventional conveyor idler rolls can act as a resonance chamber, amplifying sound created by the friction between the rollers and the belt or the idler bearings. As Flexco pointed out in literature discussing its line of composite rollers, "This noise variation can mean the difference between functioning below the maximum decibel levels and violating ordinances."

Non-metallic or coated rollers dampen resonance behavior and can lower noise levels. Most idler manufacturers offer low-noise idler construction using alternate shell materials such as aluminum, high-density polyethylene (HDPE), nylon, or coated steel rolls in combination with controlling the roll surface quality (the MIS and TIR) and dynamic balancing of the rollers. Brown's article suggests that changing idler specifications to 'low noise' or 'super low noise' can result in a 6 to 12 dBA noise reduction. One idler manufacturer has claimed as much as an 18 dBA reduction in idler noise over standard steel roll construction.

In a 2011 article in *Coal International*, "Noise emissions of belt conveyors," Adam Gladysiewicz observes that the fact that idlers and their bearings create conveyor noise can lead to a conclusion:

> ... that smaller bearing size and greater idler spacing is the most inexpensive solution [to conveyor noise]. These measures, though, lead to premature bearing

defects which, in turn, result in higher noise levels.

Other sources of conveyor noise were noted by Ben van Zyl in the paper, *Overland Conveyor Noise: Engineering Tools for Noise Reduction*, presented at Beltcon 18 in 2015. They include:

- Bearing failure produces very high levels of abnormal high-pitched noise. Only one defective bearing may ruin the performance of a long section of an otherwise quiet conveyor.
- The start-up alarm is an auxiliary source of noise often cited as a nuisance in complaints relating to conveyors.
- Empty conveyors are more noisy (typically 2 dB) than conveyors running with load.

Another influence on conveyor noise is the speed of the belt, with noise levels increasing with increasing speed. Ben van Zyl continues, "Noise levels increased by a very substantial 10 dB per doubling of speed in the range 2 to 6 meters per second [≈394 to 1,180 fpm]." (**Figure 19.3.**) As noted above, an increase of 10 dBA represents a doubling of the perceived sound level.

There is very little published on noise generated by flowing materials. The suppliers of engineering services that use discrete element method (DEM) computer software models to optimize flow through chutes typically claim noise reduction, presumably by utilizing the sliding flow of the bulk materials over bulk materials in comparison to a more noisy direct impact on the chute walls.

Other professionals prescribe overall noise reduction in transfer towers by enclosing the transfer in a building. However, as van Zyl noted:

> Secondary noise is produced by excitation of the supporting structure and by structure-borne transfer to the canopy and any steel cladding where

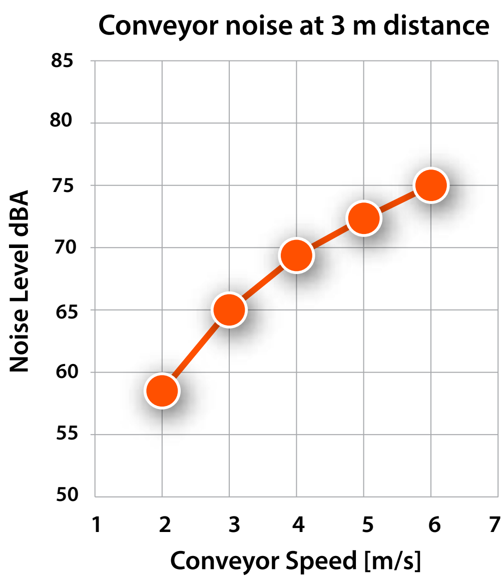


Figure 19.3.

Conveyor noise levels increase 10 dBA as belt speed doubles. Illustration after Van Zyl: Overland Conveyor Noise Engineering Tools for Noise Reduction.

Belt Flap as a Source of Conveyor Noise

Another source of conveyor noise is what is called 'belt flap.'

When a belt between two idlers is excited by an idler roll turning at or near a natural frequency of the transverse vibration of the belt span, a resonance phenomenon occurs.

This inter-idler belt vibration can be driven or excited by small idler roll run-out, TIR, or radial variation at the rotational frequency. The amplitude of transverse vibration increases considerably when resonance occurs yielding increased roll/bearing wear and an increased power consumption of the belt.

This is visible as an up-and-down oscillation of the belt between the idlers. But it is heard as a low-frequency vibration often called 'helicopter noise.' This low-frequency sound wave can travel significant distances.

Uncontrolled belt flap can increase noise two ways. First, it will add its own low-frequency oscillation noise to the general conveyor noise. Second, the vibration also causes components to degrade prematurely, increasing the chance for idler bearing squeal.

Reducing belt flap—and thus the creation of belt-flap noise—is often accomplished by varying or staggering the spacing of idlers. In addition, V-shaped return idlers can be used, as they help center the belt path and reduce vibration.

large surfaces are capable of emitting the energy as air-borne noise.

Noise from chutes is also a point source that can be significant. Many chute suppliers claim their particular techniques will reduce noise without offering specific case studies or engineering calculations. Some suppliers claim a 10 dBA reduction in chute noise by the use of rubber linings.

Figure 19.4.

Hearing protection and hearing conservation program requirements, by geographic region.

Comparison of Regulatory Requirements for Hearing Conservation Programs and Procedures

	Australia	European Union	United States
Hearing Testing Program Required	85 dBA	85 dBA	-
Hearing Protection and Warnings Required	80 dBA	85 dBA	87 dBA
Maximum Exposure under Hearing Protection	85 dBA	90 dBA	90 dBA

Figure 19.5.

Maximum recommended Noise Exposure Levels and Lengths of Time.

Courtesy of noisehelp.com.

Maximum Recommended Noise Dose Exposure Levels

Noise Level (dBA)	Maximum Time-Weighted Exposure per 24 Hours
85	8 hours
88	4 hours
91	2 hours
94	1 hour
97	30 minutes
100	15 minutes
103	7.5 minutes
106	3.7 minutes
109	112 seconds
112	56 seconds
115	28 seconds
118	14 seconds
121	7 seconds
124	3 seconds
127	1 second
130–140	less than 1 second
140	NO EXPOSURE

Another source of conveyor noise is the low-frequency oscillation called 'belt flap.' (**See Belt Flap as a Source of Conveyor Noise.**)

Conveyor noise is often increased by inadequate maintenance and replacement guidelines. Loose bolts, failing bearings, and worn shafts all contribute to the noise profile of a conveyor. Noise from idlers is increased when rolls are sometimes replaced in original frames without regard to the fit of the shaft in the frame, either by using rolls from different manufacturers or through the accumulated wear of the frame roll-holding slots over time.

REGULATIONS AND STANDARDS

While there are no regulations specifically related to conveyor noise, noise regulations around the world are in general agreement. The generally accepted standard to minimize hearing risk is based on an exposure to 85 dBA for a maximum limit of eight hours per day, followed by at least ten hours of recovery time at 70 dBA or lower—when the risk of harm to healthy ears is negligible. Brad Witt's article, "Sound Source: Changes in EU Noise Directive," available on *HearForever.com*, offers the summary of standards in **Figure 19.4**.

Above 85 dBA, a '3-dBA exchange rate' formula is applied, which means that for every 3 dBA above 85 dBA, the maximum exposure time is cut in half. As shown in **Figure 19.5**, each time interval shown represents 100 percent of the allowable noise dose per 24-hour day. If a worker experienced 15 minutes at 100 dBA, the worker should have no exposure above 85 dBA for at least 10 hours, and preferably below 70 dBA. A noise dosimeter can be worn to establish noise levels and exposure times by calculating the time-weighted noise exposure by intensity and frequency.

Noise levels above 140 dBA are not considered safe for any period of time, however brief.

All country regulations require the assessment of noise levels and the establishment of policies and procedures to mitigate hearing damage from noise exposure.

The principal exception is in the United States, which still uses an older maximum noise exposure level of 90 dBA per 8-hour day but the same threshold for establishing a hearing protection program. The Occupational Safety and Health Administration (OSHA) standard in *29 CFR 1910.95(c)(1)* requires a hearing protection assessment at 85 dBA with the threshold for a hearing conservation program starting with 8 hours of exposure at 90 dBA.

Almost all other countries require a hearing protection assessment when the 8-hour noise level exceeds 80 dBA, with hearing conservation programs required for 85 dBA exposure and above.

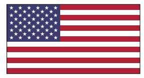
Europe

According to Brad Witt, author of *Sound Source: Changes in EU Noise Directive*, the European Union establishes an exposure limit when wearing hearing protection. This 8-hour exposure limit—defined as 87 dBA—is the maximum allowable daily noise exposure level, taking account of attenuation provided by personal protective equipment (PPE)—typically, ear plugs or ear muffs—worn by a worker. Witt's article also provides a table of the protective measures required at various noise levels by the 2003/10 EC directive. (**Figure 19.6.**)

South Africa

In South Africa, the updated standard for defining noise-impact limits and standards is *SANS 10103 Ed. 6 (2008) The Measurement and Rating of Environmental Noise With Respect To Annoyance And To Speech Communication*. This national standard is also used by local authorities in control of environmental noise.

The Mine Health and Safety Act 29 of 1996 (as amended May 2015) in section 22.9(2) established 85 dBA, (shown in the Act as 85 $dBL_{Aeq,8h}$) as the occupational exposure limit for an 8-hour working day or a 40-hour working week. The peak sound level limit is 135 dBA.



United States

In the United States, the OSHA requirement in *29 CFR 1910.95 Occupational noise exposure*, Paragraph (a) states:

> Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table G-16 when measured on the A scale of a standard sound level meter at slow response. (**Figure 19.7.**)

Controls for noise are required in *1910.95(b)(1)*, as follows:

> When employees are subjected to sound exceeding those listed in Table G-16,

EU Noise Directive 2003 10 EC Requirements

Hearing Protection Measure	2003/10 EC Directive Level
Warning Signs Posted in Work Areas	85 dBA
Hearing PPE Available to Workers	80 dBA
Hearing PPE Use Required	85 dBA
Training of Exposed Workers Required	80 dBA
Noise Reduction Program Required	85 dBA
Protection Level Required of Hearing PPE	87 dBA

Figure 19.6.

Hearing protection measures required by regulations in the European Union.

Permissable Noise Exposures

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4 ≤	115

Figure 19.7.

Table G-16, Noise exposure levels permitted by MSHA in the United States.

> feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of Table G-16, personal protective equipment shall be provided and used to reduce sound levels within the levels of the table.

In *1910.95(g)(1)*, the OSHA regulations require a testing program for "employees whose exposures equal or exceed an 8-hour time-weighted average of 85 decibels."

The Mine Safety and Health Administration (MSHA) requirements for noise exposure are covered in *30 CFR 56.5050 – Exposure limits for noise* as follows:

> (a) No employee shall be permitted an exposure to noise in excess of that specified in the table …
>
> (b) When employees' exposure exceeds that listed in the … table [**Figure 19.7.**], feasible administrative or engineering controls shall be utilized. If such controls fail to reduce exposure to within permissible levels, personal protection equipment shall be provided and used to reduce sound levels to within the levels of the table.

Hearing protection is recommended at levels above 85 dBA. A miner is overexposed when noise dosimeter measurements equal or exceed 132 percent, or sound level meter readings exceed 117 dBA. In determining a miner's exposure, MSHA does not consider the attenuation provided by any hearing protection worn.

Community Regulations

In addition to the national health and safety regulations, many local communities establish more restrictive ambient noise levels to reduce the effect of noise on people working and living near industrial, mining, and port facilities. In many cases, these local regulations are difficult to meet without enclosing noisy equipment or considering alternate haulage technology.

Because of the personal and subjective assessment of loudness, noise complaints from neighbors can be quite difficult and time consuming to quantify and resolve. Industrial sites located near residential communities may find they need to employ a full-time environmental manager to deal with neighbor complaints including noise pollution. Not only do these complaints affect the company's welcome in the community, they can be the source of regulatory investigations, fines, and even lawsuits for sleep deprivation and/or hearing damage. Because hearing loss is considered a permanent physical injury, many jurisdictions consider it to be compensatory under workers' compensation insurance and a basis for non-employees to file civil lawsuits.

Writing in *Environmental Noise and Vibration Impact Assessment for The Proposed Arnot Mooifontein Opencast Expansion Project*, Barend van der Merwe noted:

> In terms of noise increases, people exposed to an increase of 2 dBA or less would not notice the difference. Some people exposed to increases of 3-4 dBA will notice the increase in noise level, although the increase would not be considered serious. Noise increases of 5 dBA and above are very noticeable, and, if these are frequent incidents, or continuous in nature, could represent a significant disturbance.

One approach for industrial development regulations is to keep noise levels to less than 5 dBA above the ambient background noise.

Another approach is limiting the total noise levels. For example, the *Western Australian Environmental Protection (Noise) Regulations 1997* set limits for daytime, evening, and night time periods. The established noise limits for day, evening, and night are 45 dBA, 40 dBA, and 35 dBA respectively, as measured from the boundary of the facility.

Making a site noise assessment and predictions for new developments can be complex and generally require a specialized engineering firm.

Controlling Conveyor Noise

Because of the risk that neighbors and other non-workers will be affected by conveyor noise, it is recommended that efforts be undertaken to reduce the creation and release of this noise.

As Steve Morgan points out in *Applications of Noise Control in the Mining Industry*, there are "three basic approaches to protecting the individual worker from hazardous noise exposure." They are:

- Control at the source to limit the creation of noise (i.e., use of quieter components, replacement of noisy components).
- Control along the path to limit the spread of the noise (i.e., placement of walls or berms, installation of sound-absorbing insulation).
- Control at the receiver of the noise (i.e., through PPE, or removal of the worker from the noisy environment).

In his work, Morgan goes on to point out that one way to reduce noise is through the use of quieter equipment:

> This is two-pronged. The first stage involves the selection and utilization of mining machinery that is as quiet as possible. ... The second stage involves ensuring that the equipment is well-maintained from beginning to end. Key to this is replacing worn components … and adhering to good maintenance schedules.

Idlers with worn bearings increase imbalance and hence noise, so timely replacement of failing idlers is an important noise-control strategy.

Attention to belt cleaning is also critical in maintaining conveyor noise levels near the design values, as the presence of more fugitive material increases the likelihood of impaired bearing performance which will result in increased noise.

Isolating high-impact areas—such as conveyor loading points—with rubber cushions or air springs can be an effective technique to reduce noise and prolong equipment life.

When the noise source itself cannot be directly addressed, it may be possible to interrupt the noise on its path from the source to the receiver. This can be accomplished by using sound barriers such as walls or buildings to block the noise or sound-absorbing materials to reduce the amount of noise.

The sound can be directed with a canopy. But van Zyl notes that conventional canopy designs are restricted by a limitation arising from the

Measurements of Conveyor Noise in a Turkish Coal Mine

A survey of machine-related industrial noise was carried out in the operating mines of Tuncbilek Colliery of the Western Lignite Corporation (WLC) in Turkey. Results of this survey were published in the paper, "Occupational Noise in Mines and Its Control—A Case Study," by C. Sensogut which appeared in the *Polish Journal of Environmental Studies* in 2007.

All sound levels were taken 5 meters (≈16.5 ft) from the equipment being measured, using an American National Standards Institute (ANSI) S1.4 Type 2 digital sound meter.

Among the equipment surveyed for noise were the operation's belt conveyors. Sound levels produced by conveyors (and other equipment) were given in the paper's Table 1 (which is condensed into the Table shown below.

Measurements of Sound Pressure Level at WLC Tuncbilek Colliery	
Station	(dBA)
* Main belt conveyor (beside the engine)	83-84
* Transfer point of belt conveyor	78-79
** Belt conveyor for run-off mine coal	83-84
** Hand sorting conveyor	85-86
** Noise measurements from underground pits [mines] of WLC*	
*** Noise measurements from coal preparation plants of WLC*	

The paper notes, "Detailed examination … reveals the fact that in almost all of the stations both surface and subsurface from which the measurements were obtained are undesired sources of noise."

connection of the canopy with the conveyor structure. (**Figure 19.8.**) The author states:

> Because it is intimately coupled to the primary source of noise, structure-borne conveyor noise and vibration are transferred to the large canopy surfaces acting as efficient radiators of airborne sound.
>
> When considering possible improvement of the noise screening provided by the housing, the first step would be to completely detach the housing from the conveyor support framework. A doghouse canopy, for example, may still be left open on the maintenance side, but should be supported on an independent frame. On the rear side, the gap at the bottom should be reduced to the minimum required for water drainage. Once detached in this way, the noise screening performance may be improved by interior acoustic lining of the canopy.

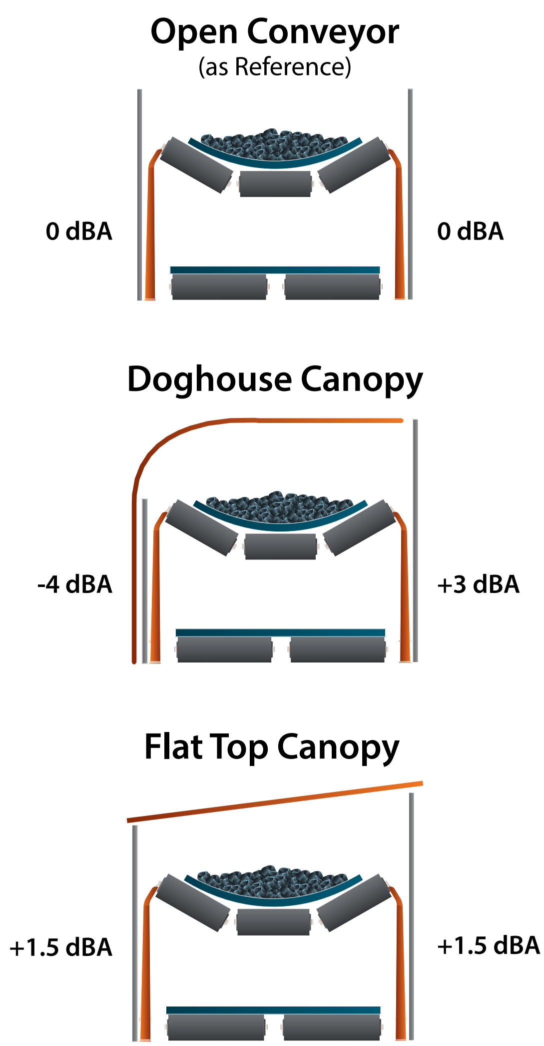


Figure 19.8.

Conveyor canopies of various designs offer differing amounts of noise reduction.

(Illustration after Van Zyl: Overland Conveyor Noise Engineering Tools for Noise Reduction.*)*

Another method to control noise is the construction of barriers. A noise barrier might consist of a berm, a wall, or a combination of the two. (**Figure 19.9.**) Ben van Zyl notes that a berm does have certain advantages over a vertical wall in that "it provides a small degree of absorption. More importantly, the sloped face on the side of the conveyor reflects conveyor noise skywards, rather than horizontally."

BEST PRACTICES
Reducing Conveyor Noise

The deleterious effect of noise on the hearing, health, safety, and productivity of workers and neighbors is well documented. Protecting workers and neighbors from excessive conveyor noise is a requirement and also makes financial sense.

Management should:

- Use the globally accepted levels as reflected in *EU Directive 2003/10/EC* as a guide for establishing hearing conservation policies and procedures.
- Conduct audiometric testing of all workers at least every three years and maintain test results in the employee's permanent file.
- Conduct comprehensive noise surveys every three years to identify new noise sources and intensities due to equipment or process changes.
- Limit worker exposure times and provide recovery periods.
- Provide proactive training to supervisors and noise-exposed workers on the effects of noise, hearing protection, and mitigation techniques.
- Include workers in the choice of suitable hearing protection PPE and noise-mitigation efforts.
- Comply with site noise-limiting requirements from all jurisdictions.

- Include maximum noise level requirements in system design specifications, and require evaluation of sound and vibration isolation techniques to exceed noise regulations.
- Evaluate the potential for belt flap in the initial design phase; use V-return idlers to limit flap.
- Reduce chute noise.
  - Use DEM in chute design reviews to minimize bulk material impact.
  - Use low-noise liners such as ultra high weight polyethylene (UHMW PE), rubber, or sprayed urethane.

Conveyor designers, owners, and operators should consider the following approaches to mitigate conveyor noise:

- Enclose the conveyor belt.
  - Consider installing barrier fencing beside the conveyor.
  - Use the topography or build berms to reduce lateral noise propagation.
  - Place transfer points inside buildings.
- Consider installation of air-supported belt conveyor(s), which often operate 10 to 15 dBA quieter than conventional roller-supported conveyors.
- Use low-noise conveyor rollers.
- Reduce the adhesive-release noise between the belt and rollers. One approach is to require noise-level testing between the roller and belt as part of any belt/roller-indentation resistance testing.
- Consider conveyor belt cleaning by belt washing to reduce dirt and carryback buildup to a minimum.
- Immediately replace noisy components, such as squealing bearings in idlers.
- Use both audible and visual warning signals; audible signals should be at least 10 dBA above the background equipment noise.
- Isolate noisy sections of the conveyor using rubber blocks or air springs.
  - Isolate chute sections where vibrators are used to induce flow.
  - Isolate conveyor structure in high noise-generating sections such as impact zones.
- Keep conveyor idlers and pulleys aligned to Conveyor Equipment Manufacturers Association (CEMA) Standards.
- Replace idler frames when the idler shaft slots wear.
- Use professional maintenance contractors to maintain conveyor components that

2

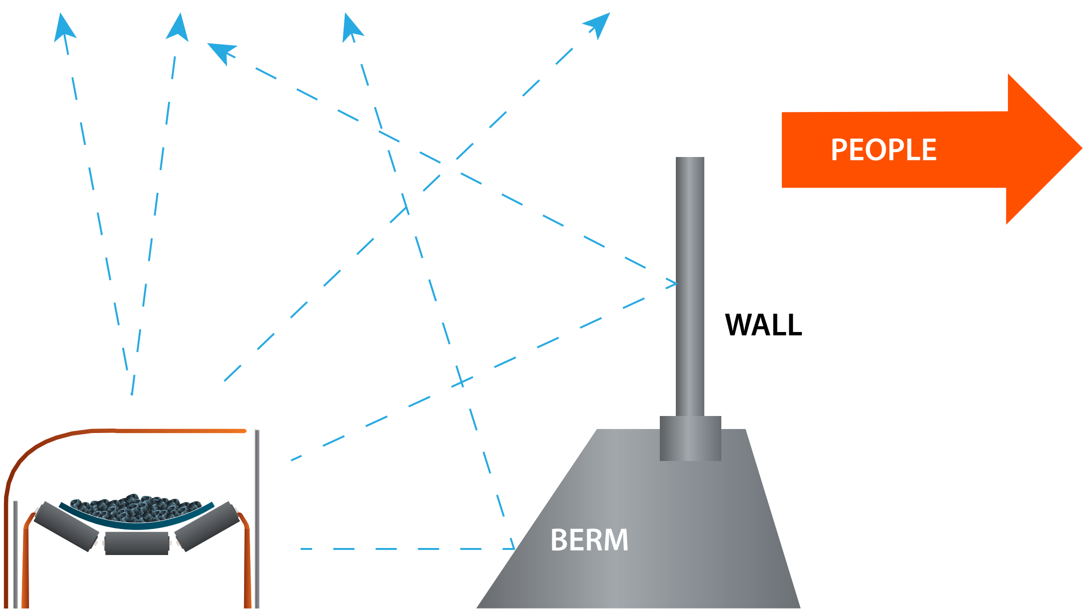


Figure 19.9.

A wall on top of the berm surmounted with a wall can be installed to deflect conveyor noise.

(Illustration after Van Zyl: Overland Conveyor Noise Engineering Tools for Noise Reduction.*)*

can directly or indirectly generate excessive noise.

CLOSING THOUGHTS
Keeping It Quiet

Controlling conveyor noise can be difficult but there are effective mitigation techniques beyond worker PPE to reduce conveyor noise. As noted by Steve Morgan in the web article, "Noise Control Applications in the Mining Industry," the best protection against noise-induced hearing loss "results from a comprehensive noise control program that addresses noise at the source, interrupts noise on its path, and shields receivers from the noise." This three-part program can certainly be applied to the noise of bulk-materials-handling belt conveyors. ⚠

2

Chapter 20 Signage

INTRODUCTION

The Need for Signage

Conveyors, like most machines, have hazards that are not obvious or that change with alterations in operating parameters, weather conditions, or overall processes. The location of a conveyor can create potential hazards such as restricted access to emergency exits, falls from heights, or unsafe atmospheres. Many potentially dangerous situations cannot be controlled easily with guards, personal protective equipment (PPE), or work procedures; signs offer a proven way to warn and so add an extra layer of protection. Signs serve as reminders, help identify safety equipment, direct people to safe egress, and help communicate the policies for safety and security.

Standards for warning signage from both the American National Standards Institute (ANSI) and International Organization for Standardization (ISO) provide excellent guidance, so it is not the intent of this section to give detailed advice on designing signage. Rather, this section provides an overview of warning and notice signs, labels, and tags, referred collectively to as signage, as they relate to the hazards associated with bulk-materials-handling conveyors.

To be effective, signage must be used in combination with other safety tools such as training and guarding.

Issues with Signage

Safety signs can provide some risk reduction for industrial operations. However, it must be emphasized that these warnings, like PPE, do not alleviate the presence of the hazard.

Generally, warning labels and signs are effective if observed. But of course, that is a big variable. One problem is that humans tend to become familiar with the signs as background information, and so the signs lose their effect over time due to a phenomenon called 'alert fatigue.' Often there are multiple and conflicting warnings within a relatively short distance that add to alert fatigue and a worker's propensity to ignore warnings.

Another common problem in mining and industrial workplaces is a lack of adequate lighting for noticing and reading warning labels and signs.

In addition, the replacement of worn or damaged warning signs and cleaning or removing obstructions is typically a low-priority task for the plant and so, over time, warnings become unreadable. (**Figure 20.1.**)

It is the end user's—factory owner's/manager's—responsibility to keep signs clean and visible. Worn, damaged, or unreadable signs and equipment labels should be replaced, including the labels supplied by third parties on individual components.

It should be noted that as people age, their ability to distinguish colors diminishes; consequently, the value of color in a warning loses impact.

All of these issues contribute to diminish the effectiveness of warning labels and signs.

Signs can be moderately effective in reducing accidents and injuries and have become a common hazard recognition tool. Workers become too used to them, complacent about the content, or even intentionally disregard them. Signs by themselves do not reduce a hazard or control the risk, and therefore, have limited effectiveness as a method of hazard control. (**Figure 20.2.**) Signs must be used in conjunction with other controls.

Signage Compliance

When a company sells products globally, its desire—for simplicity's sake—would be to have one standardized signage system. For companies that operate on only a national level, compliance with those national and regional regulations will be sufficient. But this may not be the best practice for signage, so the quest to standardize safety signage is more difficult than necessitated by the simple need to be safe.

Signs are formatted and used in several ways. Modern safety signage conveys the nature of the hazard, the consequence of interaction with the hazard, and how to avoid the haz-

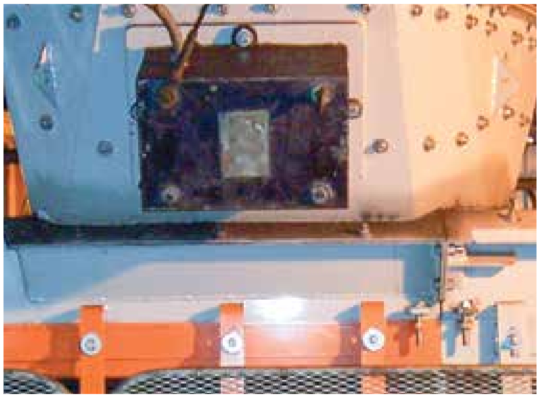


Figure 20.1.

Over time, signs can become unreadable due to obstructions or the accumulation of dirt.

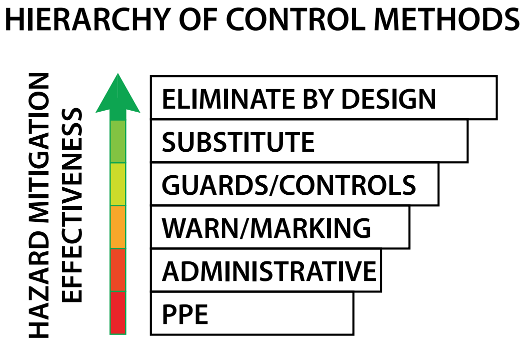


Figure 20.2.

As a midpoint on the hierarchy of control methods, signage has limited effectiveness in improving safety.

2

ard. Unfortunately, signage—like most safety standards—is not harmonized, making global compliance with standards more complex than necessary. *ANSI Z535* and *ISO 3864* are the two most common standards appropriate for conveyor safety signage. There are many other standards, such as Canada's *CSA Z321* or Australia's *AS1319-1994*.

Both ISO and ANSI signage standards are based on human behavior research and standardized risk-severity levels. ISO, to reduce the dependency on language skills, relies on pictograms in standardized shapes and colors that denote *HAZARD* awareness, *PROHIBITED* actions, and *MANDATORY* requirements.

ANSI combines the risk and severity of the hazard notice with pictograms and word descriptions using signal words—in descending order of risk—*DANGER*, *WARNING*, and *CAUTION* in defined color schemes.

Warning Signs and Labels

Both ANSI and ISO allow a wide range of layouts for safety signs and labels. The most commonly used ANSI-compatible layouts are shown in the **CEMA's Safety Label Program** sidebar. Labels are generally formatted similar to signs but with dimensions appropriate for the space available for mounting.

CEMA's Safety Label Program

In an effort to promote standardization and safety in the conveying industry, the Conveyor Equipment Manufacturers Association (CEMA) has developed a family of safety labels.

The CEMA standardized safety labels and associated literature are focused toward the typical hazards encountered when using conveying equipment. (Shown below.) CEMA labels comply with the *ANSI Z535* Safety Alerting Standards.

As the CEMA website notes in its Safety Labels Placement Guidelines:

> The label and placement program is intended as a voluntary guide and should be incorporated into a comprehensive safety program by users of conveyors and related equipment as part of their effort to prevent injuries.

CEMA safety labels (stickers) are designed with three components: an Alert (Danger/Warning/Caution), a Pictogram (a non-verbal depiction of the conduct to be avoided) and a Message (the words used to enhance the message depicted by the Alert and Pictogram).

The labels and the placement guidelines were developed by the CEMA Safety Committee to provide advice for the selection and application of safety labels for use on conveyors and related material-handling equipment to assist in accident prevention.

While the label program covers many classes of conveyor, CEMA has identified the labels that belong on bulk-materials-handling belt conveyors, as well as accessories used on bulk-materials-handling conveyors (Shown on right), and identified the optimal locations to place the labels. (Shown far right.)

The **Safety Label Placement Guidelines** are contained in the 36-page *Safety Label Brochure* (CEMA

One requirement is that the warning label or sign be visible at a sufficient distance to allow the worker to read the sign and avoid the danger. Obviously then, this viewing distance will affect the size of both the lettering and of the overall sign or label.

In addition, the wording on any safety sign should be concise and easy to read. *ANSI Z535.2* provides guidance on the appropriate size for lettering in both favorable and unfavorable conditions for reading. Minimum safe distances are specified; this represents the distance a worker can be from the sign and still have time to comply with the sign's message and so avoid the hazard. The standard also specifies that the signal words—Danger, Warning, Caution—should be at least 50 percent greater than the height of a capital letter in the message.

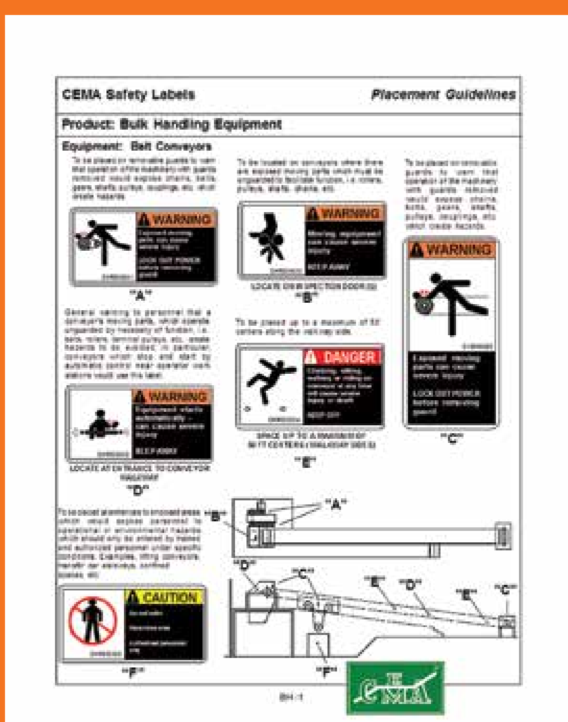
Warning signs and labels are often used to comply with the theory that the manufacturer and the owner of the equipment have a 'duty' to warn owners, employees, and contractors of that equipment's hazards and potential for harm. Generic safety labels are available from many safety supply houses; safety labels specifically designed for conveyors can be obtained from the Conveyor Equipment Manufacturers Association (CEMA).

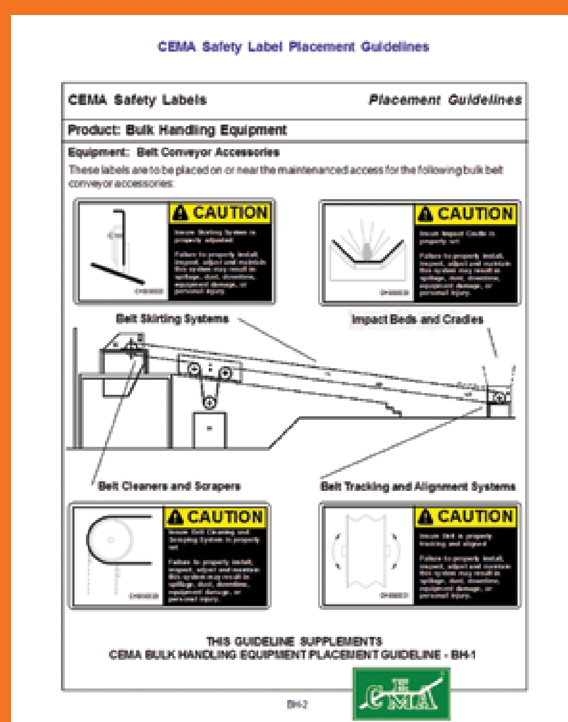
Brochure # 201), which is available for purchase from *cemanet.org/cemastore.com*.

The CEMA website also notes, "Should any of the safety labels supplied by an equipment manufacturer become unreadable for any reason, the equipment USER is then responsible for the replacement and location of the safety labels."

CEMA intentionally does not copyright safety labels so users are able to use the pictograms and translate the text for their specific uses.

Labels are available in English, in regular (interior) duty and severe (exterior) duty in rolls of 250. Safety labels and the related publications can be obtained from *www.cemanet.org.*





Warning Tapes and Notice Tags

Safety tags—for example, those used in lockout / tagout—should be specific to the hazard or notice being given. Safety tags and notices—for example: tagging a defective idler for maintenance—should be consistent with the ANSI or ISO color schemes in use at a facility but can be of various designs depending upon the equipment and hazard being tagged.

However, only one tag format for each specific hazard or notice should be used throughout a facility.

Warning/Barricade Tape

Barricade tapes may be red, orange, or yellow with the DANGER, WARNING, or CAUTION signal word, respectively, as appropriate for the type and immediacy of the potential hazard involved. Usually, the signal word is in black.

Warning/Barricade tapes should not be used as a permanent means of warning. These tapes are for temporary conditions such as to block off an active work site or identify a hazard that will be remediated in the near future. As such, the materials used for warning/barricade tapes are not intended for prolonged exposure to the elements or industrial environments. Barricade tapes are easily damaged and like other safety-warning messages should be replaced if they become illegible, dirty, or broken.

Figure 20.3.

Tags are used as a means to protect workers exposed to temporary hazards.

Notice Tags

Tags shall be used as a means to prevent accidental injury or illness to workers who are exposed to hazardous—or potentially hazardous—conditions, equipment, or operations which are out of the ordinary, unexpected, or not readily apparent. (**Figure 20.3.**) Tags should only be used for temporary hazards. Tags shall be in place until such time as the identified hazard is eliminated or the hazardous operation is completed. Tags need not be used where signs, guarding, or other positive means of protection are being used.

Tags are generally designed in accordance with the standard used for safety-warning signs with consideration to their typically smaller size and the need to allow space for hand-written information. Usually a tag will have a means for temporary attachment such as a wire or string.

As specified in the United States Occupational Health and Safety Administration (OSHA) regulation *29 CFR 1910.145(f)(4)(ii)*, (and as understood to be present in the 2016 revision of *ANSI Z535.5*) the signal word—i.e., Danger, Caution, or Biohazard—on a tag should be "readable from five feet (≈1.52 m)." Obviously then, the tag itself will be visible from at least that far.

One common use for a tag is to identify a worker's lockout / tagout padlock while providing information on the nature of the work being done and the name and contact information for the worker.

The Psychology of Safety Signage

Unfortunately, warnings often fail to change people's behaviors. Either the warnings goes unnoticed, or as increasingly happens, the warning is seen but ignored. (**Figure 20.4.**)

Some of the same behavioral factors that lead workers to make a decision leading to an unsafe act also apply to the worker heeding (or ignoring) safety signage. As Marc Green points out in "The Psychology of Warnings," an article posted on *Visualexpert.com*:

> It is perceived risk, perceived hazard, perceived control and perceived norms that matter, not actual ones. This may be obvious, but is worth saying explicitly since many of the people who design warnings are engineers. They are not so likely to consider mental models or psychological concepts.

First of all, the worker who sees a sign must decide whether or not to comply. This decision is influenced by the worker's general understanding (or misunderstanding) of how the world works in relation to the task at hand.

Secondly, the worker usually has an experienced-based feeling for the risk, which may or may not be accurate.

Finally, the worker starts the task with a goal and a strategy for achieving that goal. The goal can be specific—'I want to complete the work as soon as possible'—or more diffuse—'I want to make sure the breakdown does not happen again.'

If a warning tells the worker to refrain from behavior that would enable the direct and easy achievement of a goal, then the sign-reading worker makes a cost-benefit analysis.

In making this analysis, the worker then must take both hazard and risk into account. If the worker believes that there is great danger, then there will be a larger benefit in compliance with the warning sign. Conversely, the perception of small danger means little benefit for compliance and so compliance will decrease.

Green offers an overview to summarize the psychology of warning signs:

> In sum, people who view warnings use a mental model to perform a cost-benefit analysis. The three main process components are 1) cost of compliance, 2) perception of danger level and 3) personal and social and cultural decision-making factors.

The Differences Between Standards

ISO standards place a heavier reliance on pictorial warnings than the ANSI standards. In fact, the ISO warning can be exclusively pictorial. By contrast, the ANSI standard mandates that a signal word and a message panel provide necessary information to the product user. (**Figure 20.5.**)

It should be noted that neither the ANSI nor the ISO warning schemes have the force of law. The differences between these two approaches can cause possible safety issues and potential litigation problems. If a manufacturer, adhering to the ISO standard, exports its products to the United States, that manufacturer is at risk for liability based upon failure to warn. The liability stems from the manufacturer's 'failure to warn' to the relevant United States standards.

In addition, the goals of the two systems, while similar, are not exactly the same, according to a 2011 article, "Conflicting Issues Regarding Warning Labels May Be Hazardous to Your Company's Health," written by Jonathan R. Cooper and Arun J. Kottha and published in the *In-House Defense Quarterly*, a publication for corporate attorneys. To Cooper and Kottha, ISO's goal is "to alert persons to a specific hazard and to identify how the hazard can be avoided," whereas

Figure 20.4.

As signs become familiar, their warnings may go unnoticed or be ignored.

2

ANSI's goals are:

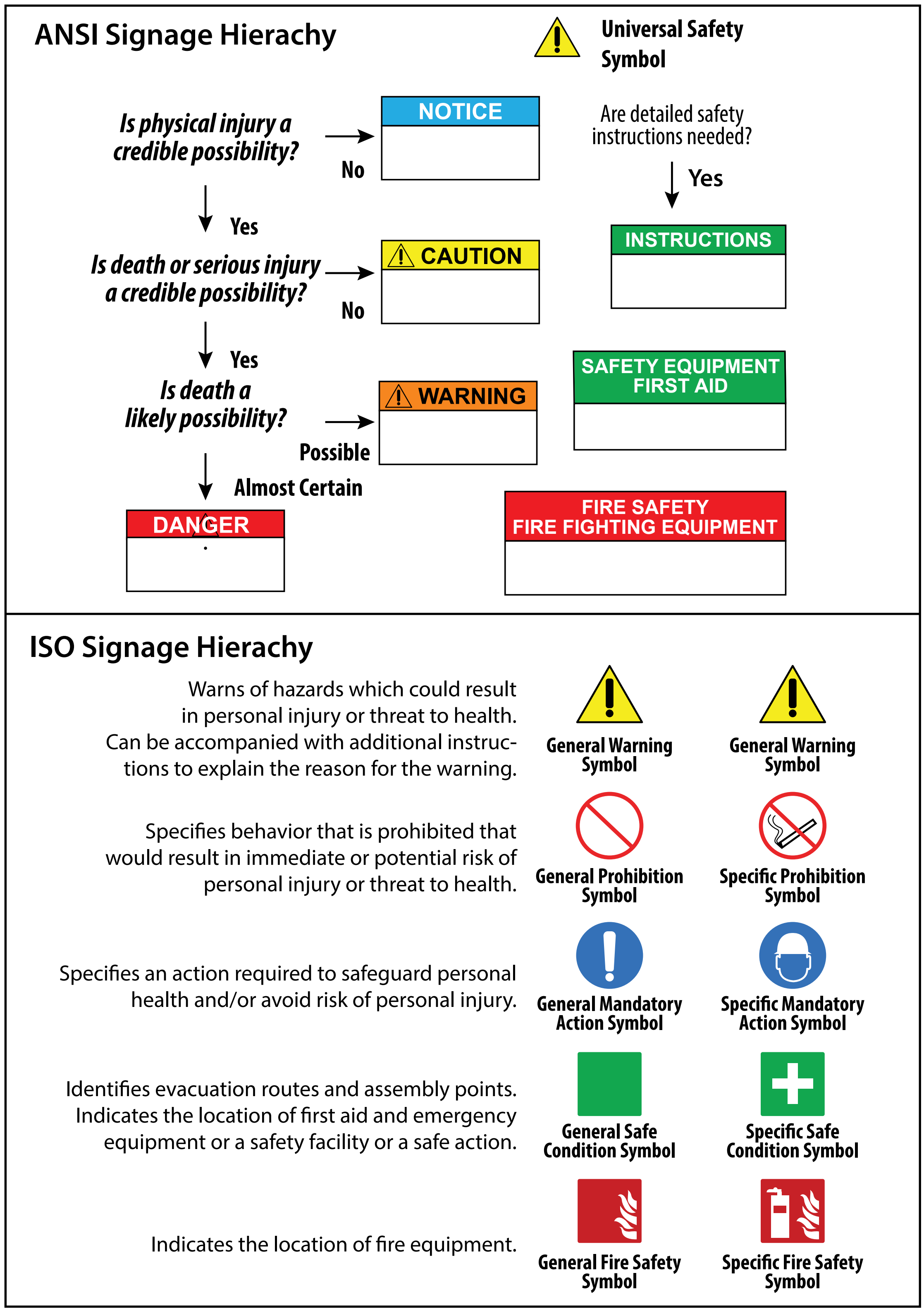
(1) to establish a uniform and consistent visual layout for safety signs and labels applied to a wide variety of products;

(2) to minimize the proliferation of designs for product safety signs and labels; and

(3) to establish a national uniform system for the recognition of potential personal injury hazards for those persons using products.

Figure 20.5.

The requirements of ANSI and ISO signage programs are compared.



The ISO system is less concerned with variation and more concerned with adapting safety labels to specific situations. By contrast, ANSI is more concerned with a standardized system. As noted by Cooper and Kottha:

> ANSI's theory is that … workers will be safer because they become conditioned to respond to the same signal words and warning style so they heed warnings when they are exposed to them year after year. …
>
> It is possible to harmonize ISO and the ANSI standards into a single 'hybrid'0 label. An ISO-ANSI-hybrid warning label would have an ISO image accompanied by an ANSI-compliant message panel and signal word. This would ostensibly satisfy the visual ISO requirements and supply the required text of the ANSI requirements.

But as Cooper and Kottha continue, "This solution is not perfect."

The ISO system does not require any verbiage at all. If one does include a text passage, ISO provides no guidance about the language that should be used. The specified color schemes are slightly different. However, the hybrid label is very close to full compliance with both standards.

Figure 20.6 shows graphical approaches from several standards for safety signs noting mandatory hardhat usage. The *ANSI Z535* standard allows the use of the graphics in other standards (*ISO 3864* in this case). The hybrid type of signage shown under *ANSI Z535* in **Figure 20.6** is one approach for multinational corporations trying to standardize safety signage in their facilities.

REGULATIONS AND STANDARDS

A large set of existing standards provides voluntary recommendations regarding the use and design of safety information. These standards have been developed by multilateral groups and agencies. Standards-issuing bodies have represented international agencies including the United Nations, the European Economic Community (EEC's EURONORM), the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC); and national groups, such as the American National Standards Institute (ANSI), the British Standards Institute (BSI), the Canadian Standards Association (CSA), the German Institute for Normalization (DIN), and the Japanese Industrial Standards Committee (JISC).

Among consensus standards, those developed by ANSI in the United States are of special significance. Since the mid-1980s, five new ANSI standards focusing on safety signs and labels have been developed and one significant standard has been revised. The new standards are:

- *ANSI Z535.1 Safety Colors*
- *ANSI Z535.2 Environmental and Facility Safety Signs*
- *ANSI Z535.3 Criteria for Safety Symbols*
- *ANSI Z535.4 Product Safety Signs and Labels*

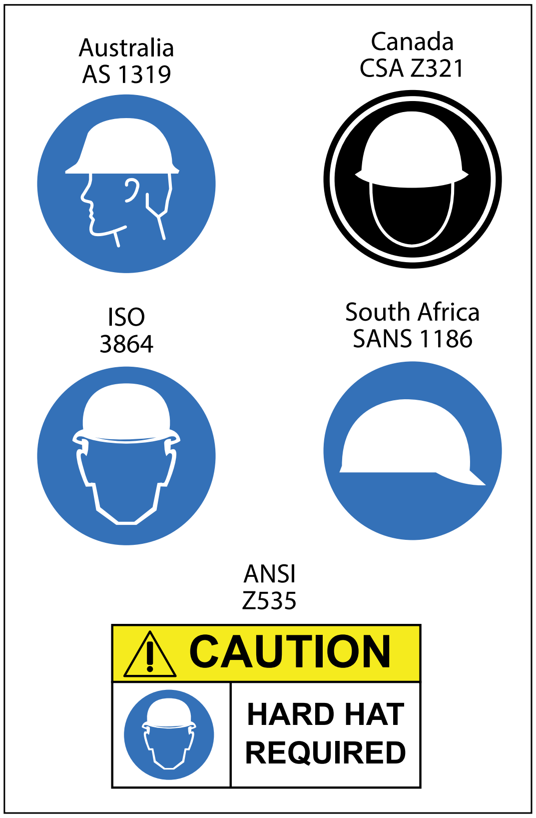


Figure 20.6

These pictograms represent 'Hard Hat Required' in various national standards.

2

- *ANSI Z535.5 Safety Tags and Barricade Tapes (for Temporary Hazards)*

While there are many warning systems, the *ANSI Z535* series of standards seem to be the most commonly followed. The *ANSI Z535.1* color scheme also seems to be most common and appropriate for conveyor markings. (**Figure 20.7.**)

Australia

The Australian standard covering safety signs is *AS1319-1994 Safety Signs for the Occupational Environment*. To comply with *AS1319*, the website *australiansafetysigns.net.au* advises:

> Safety signs are classified and shall be used according to their function as follows:
>
> ***Regulatory signs***
>
> Signs containing instructions with which failure to comply constitutes either an offence at law, or a breach of standing orders, safety procedures or other directions, depending on which kind of control has been imposed at the work site or workplace. They are subdivided as follows:
>
> (i) *Prohibition signs*
> Signs that indicate that an action or activity is not permitted.
>
> (ii) *Mandatory signs*
> Signs that indicate that an instruction must be carried out.
>
> (iii) *Limitation or restriction signs*
> Signs that place a numerical or other defined limit on an activity or use of a facility.
>
> ***Hazard signs***
>
> Signs advising of hazards. They are subdivided as follows:
>
> (i) *DANGER signs*
> Signs warning of a particular hazard or hazardous condition that is likely to be life-threatening. [This category of sign is ONLY to be used IF there is a likelihood of fatality should the message be ignored.]
>
> (ii) *Warning signs*
> Signs warning of a hazard or hazard-

Figure 20.7.

The color scheme specified in ANSI Z535.1 *seems to be the most common and appropriate for conveyor markings.*

Safety Color	Signal Word	Meaning
	DANGER	Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.
	WARNING	Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
	CAUTION	Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices.
	NOTICE	Indicates a statement of company policy directly or indirectly related to the safety of personnel or protection of property.
	GENERAL	Indicates general instructions relative to safe work practices, reminders of proper safety procedures, and the location of safety equipment.
	FIRE	Indicates the location of emergency firefighting equipment.
	DIRECTIONAL	Combinations of safety black with safety white or safety yellow are used to designate traffic or housekeeping markings.
	SPECIAL	

ous condition that is not likely to be life-threatening.

*NOTE: The term caution used in earlier editions of this Standard has now been replaced by the term warning.

The *AS 1319* standard also discusses emergency information signs and fire signs. These two types indicate the location of, or directions to, emergency-related facilities such as exits, safety equipment or first aid facilities, or fire alarms and fire-fighting equipment, respectively.

In section 4.2.3 Regulatory and hazard signs, *AS 1319 Safety Signs for the Occupational Environment* discusses sign placement. The standard notes signage should be placed so that after seeing the sign a person has sufficient time to react to it.

Canada

In Canada the standard is *CAN/CSA Z321-96 Signs and Symbols for the Workplace* is no longer mandated but is still widely used.

Europe

Originally issued in 1992, the European Union's *Directive 92/58/EEC – safety and/or health signs* specifies requirements for the provision of safety and/or health signs at work. Annexes of the directive provide detailed information about the minimum requirements for all safety and health signs.

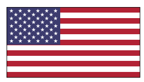
In the United Kingdom, the Health and Safety Executive offers *Safety signs and signals*, a guidance manual offering "practical advice on how to comply with the *Health and Safety (Safety Signs and Signals) Regulations 1996*." Those regulations:

> ... implement European Council Directive 92/58/EEC on minimum requirements for the provision of safety signs at work. They require employers to provide safety signs where other methods, properly considered, cannot deal satisfactorily with certain risks and where the use of a sign can further reduce that risk.

The standard that meets the directive is the most current version of the *ISO 3864* series of standards which specify design requirements, including shapes and colors, for safety signs.

South Africa

In South Africa, according to the "Safe-T-Sign at the workplace" page on *Foresightpublication.co.za* website, "The use of geometrical shapes, colours and pictorial symbols, complying with *SANS 1186-1* fulfills the requirement by conveying safety messages at a glance."



United States

The ANSI standard has six different parts:

- *ANSI Z535.1-2011 - Safety Colors*

  Provides color standards and tolerances as well as technical definitions.
- *ANSI Z535.2-2011 - Environmental and Facility Safety Signs*

  Describes the five types of safety signs used in facilities and outlines their use for consistent reinforcement and prevention of injury.
- *ANSI Z535.3-2011 - Criteria for Safety Symbols*

  Lists criteria for use of safety symbols to identify specific hazards and help people avoid injury.
- *ANSI Z535.4-2011 - Product Safety Signs and Labels*

  Sets design criteria for use of safety signs on products.
- *ANSI Z535.5-2011 - Safety Tags and Barricade Tapes (for Temporary Hazards)*

  Provides design, application, and use criteria for barricade tape, tags, and other means of identifying temporary hazards.

- *ANSI Z535.6-2011 - Product Safety Information in Product Manuals, Instructions, and Other Collateral Materials*

  Provides information for providing clear, effective safety instructions such as owner's manuals, assembly instructions, user guides, and maintenance instructions.

In the United States, OSHA regulations are set forth in *CFR 29 section 1910.145*. These regulations require the use of safety signs to indicate and define specific hazards that, without identification, may lead to accidental injury to workers and/or the public or to property damage.

OSHA also regulates the design of the actual sign. Signs need to have rounded or blunt corners and cannot have sharp edges or projections. Red, black, and white are the colors designated for danger signs. Caution signs have a yellow background, and the panel is black with yellow letters. Text used on the yellow background must be black. OSHA requires the wording of safety signs to indicate positive actions rather than negative, and to be concise and easy to read.

Manufacturer or Owner: Who is Responsible?

It is the manufacturers' or integrators' responsibility to provide warnings of reasonably foreseeable hazards for the expected and intended use of the equipment or systems they provide. Warnings come in the form of instruction manuals and signage. It is the responsibility of the user to provide training on safe use of the equipment based on the materials supplied and the site-specific use of the equipment or system. It is the user's responsibility to replace missing, worn, or illegible signage. (**Figure 20.8.**)

Figure 20.8.

It is the user's responsibility to replace missing, worn, or illegible signage.

Conveyors are usually built and installed for prolonged use. During the period between the design date and the current use, the applicable standards can change. When equipment is repurposed or has been purchased used, the line of responsibility for adequate warnings is less clear, and the user should not assume the equipment has adequate safety features or signage. Most manufacturers and integrators offer training assistance, replacement signage, and safety evaluations of their equipment upon request.

BEST PRACTICES

Material in the Best Practices below was distilled from "7 Steps for Effective Safety Signage," by Paul Lawton available on *ehsdailyadvisor.blr.com*, and from *New OSHA/ANSI Safety Sign Systems for Today's Workplaces: A Clarion Implementation Guide* from *Clarion Safety Systems.*

- Identify all hazards:
  - o Identify all the potential hazards in all parts of your facility.
  - o Identify those that are out of the ordinary, unexpected, or not readily apparent.
- Select or design appropriate safety signs [labels] and tags:
  - o Signs and tags should also be consistent in format throughout the facility.
- Ensure proper wording, graphics, and colors:
  - o Use ANSI or ISO standards for selecting and/or designing safety signs and tags.
- Position signs carefully:

- o Signs should be easily visible and legible from a distance. They must be placed to draw maximum attention to the existing hazards.
- o Signs should be placed in locations that give workers enough time to avoid the hazard.
- o For high-located placement (e.g., fire and safety equipment location signs, high-located EXIT signs), place the sign at least 78 in. [≈2 m] above floor height.
- o For medium-located placement, typically, place the sign's center 45 in. [≈1,150 mm] to 66 in. [≈1,675 mm] above floor height.
- o For low-located placement (e.g., signs marking egress paths), the top of the sign should be placed no more than 18 in. [≈450 mm] above floor height so the sign can be seen in smokey conditions.

- Identify safety equipment and fire protection equipment:
  - o Identify all safety equipment such as eyewash stations and safety showers.
  - o Identify all fire equipment.
- Use tags properly and effectively:
  - o Use tags as a means to identify temporary hazardous or potentially hazardous conditions, equipment, or operations.
  - o Remove tags when the identified hazard is eliminated or the hazardous operation is completed.
  - o Tags should be readable at a minimum distance of 5 feet [≈1.5 m] or such greater distance if warranted by the hazard.

Futhermore, it is important to maintain the signage program by:

- Place new signage whenever new hazards are introduced.
- Annually inspect, replace, and clean all warning signs.
- Relocate signs when making changes or alterations that affect the visibility or usefulness of existing signs.
- Relocate signs when equipment or materials that pose the hazard are moved.

CLOSING THOUGHTS
Sign of the Times

When properly designed and placed, signs give people warning, illustrate the potential severity of not following the warning, and offer instructions on how to avoid the hazards. (**Figure 20.9.**)

Marc Green concludes his article "The Psychology of Warnings" on *visualexpert.com* with this thought:

> There is much more to creating effective warnings than choosing the right color, size, location and font or even the right message. It is imperative to understand what the viewer is trying to achieve and how the warning affects attainment of his/her goal. Next, the designer must consider the cost-benefit calculations that the viewer is likely to perform. Finally, the designer must consider the viewer's experience and knowledge and how s/he fits into the social world.

The attention paid to a signage program is a direct indication of the safety culture of an operation. Keeping signage clean, maintained, and current is one way to show that safety is important. ⚠

Figure 20.9.

When properly installed and maintained, signs provide a valuable benefit to an operation's safety program.

2

2

Chapter 21 Electrical Safety Around Conveyors

INTRODUCTION
Electricity, Conveyors, and Workers

A review of the literature on electrical safety shows how quickly the reader is immersed in 'electrician talk,' involving terms and situations that only trained electricians or electrical engineers understand.

So the question arises: Why not leave the issue of electrical safety to the electricians, those craftsmen who are skilled, trained, and experienced in working around the wiring, motors, power lines, transformers, and other components of industrial electricity?

The fourth most common injury in the workplace is electrocution or electric shock. Getting 'zapped,' shocked, or burned are common results of electrical injuries that can often be serious or even fatal. Workers who deal specifically with electricity on a daily basis are at increased risk for such injuries; workers who are unfamiliar with electrical components and maintenance procedures, even though they have less exposure, are also subject to significant risk.

This chapter is intended to help the worker, who is not a trained electrician, stay safer when working around common electrical systems as they are applied to operations handling bulk materials by a belt conveyor.

The Belt Conveyor and Electricity

Conveyors are generally considered mechanical systems, and many conveyor hazards are mechanical in nature.

But, conveyors use numerous low- and high-voltage circuits, which can be either alternating current (AC) or direct current (DC). Both types of voltage present the hazard of electrical shock and possible electrocution.

According to the Conveyor Equipment Manufacturers Association (CEMA) reference, *Belt Conveyors for Bulk Materials 7th Edition*:

> For conveyors, alternating current (AC) squirrel cage induction or wound rotor induction motors (WRIM) are most common. Direct current (DC) shunt or compound wound rotating enclosed machines are seldom used anymore.

Belt Conveyors for Bulk Materials continues:

> … Belt drive systems range from fractional horsepower to multiples of thousands of horsepower. Small drive systems are often below 50 horsepower (<37 kW). Medium systems range from 50 to 1000 horsepower (37 to 750 kW). Large systems can be considered above 1,000 horsepower (>750 kW).

The CEMA reference lists common motor voltages used on conveyors as 230, 460, 575, 950, 2,300, 4,160, and 6,600 VAC.

There are various types of motors and power connections, and this is compounded by the use of portable (that is, mobile) conveyor systems and portable plants. The bad news regarding the portable plants is that they are mobile and subject to damage through their repeated installation and teardown cycles. The trade-off is that because they will be moved and reinstalled on a periodic basis, the portable plants should receive more attention and inspection than a permanent plant's systems that are often installed and then 'forgotten' until there is a problem.

Conveyors are often sited in difficult terrain and expected to operate under challenging situations, including adverse weather and in a dirty or neglected condition. These circumstances make it doubly important that the electricity is properly handled. If the wiring is not done properly and enclosed in conduit, it can be a hazard. (**Figure 21.1.**) The conveyor structure can become energized by contact with wiring that has worn through its protective insulation.

In addition, many conveyors incorporate or connect to other types of electrical systems and components.

The Risks of Electricity

The website *reliableplant.com* article, "Safety tips to help avoid industrial electrical injuries," states:

> According to the National Institute for Occupational Safety and Health (NIOSH), there are four main types of injuries that can occur as a result of electricity-related accidents: electrocution (which refers to the stopping of a heart due to an electric shock), electric

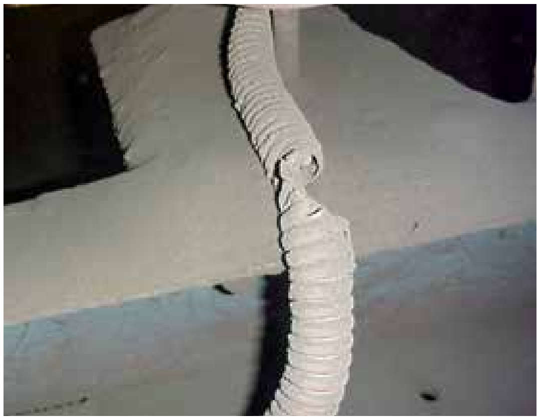


Figure 21.1.

Wiring not properly enclosed in conduit can pose an electrical hazard.

> shock, burns and falls caused as a result of contact with electrical energy.

A 2015 paper, *Occupational Injuries From Electric Shock and Arc Flash Events*, by Richard Campbell and David Dini and published by the Fire Protection Research Foundation offers the following discussion of injuries:

> The principal injury events associated with electrical hazards are electric shocks and arc flash and arc blast. Low-voltage shock injuries result from direct contact of the victim with electric current, while high-voltage shocks typically create an arc, which carries electric current from the source to the victim without any direct physical contact. Electric arcing, commonly referred to as arc flash, occurs when current passes through air between two or more conducting surfaces or from conductors to ground, and it has a variety of possible causes, including gaps in insulation, corrosion, condensation, and dust or other impurities on a conducting surface. Electric arcing may produce temperatures as high as 35,000 degrees and may cause severe burns, hearing loss, eye injuries, skin damage from blasts of molten metal, lung damage, and blast injuries.

Of course, an electric shock can also lead to other forms of injury. These would include falls resulting from a 'startle reaction' from an unexpected electric shock, as well as burns directly from a fire that has resulted from a fault.

Another hazard of electricity is electrical fires. A Joe O'Connor article, "Fire in the Workplace," published in the January 2004 issue of *Electrical Contractor* magazine notes:

> Electrical fires account for 22 percent of workplace fires. They are frequently caused by defects in wiring, motors, switches, lamps, and heating elements. ... The heat or sparks generated by the defects can easily ignite combustible and flammable materials.

Electrical Shock

Electrical shock can only occur when contact is made between two points of a circuit when voltage is applied across a victim's body.

Electrical shock can have effects on the human body ranging from minor to fatal. More serious shocks lead to burns and damage to internal organs. Even a shock that does not result in serious injury can be a root cause for other accidents, such as falling from a height when unexpectedly shocked.

Electricity requires a complete path (circuit) to continuously flow. Without two contact points on the body for current to enter and exit, respectively, there is no hazard of shock. This is why birds can safely rest on high-voltage power lines without getting shocked; they make contact with the circuit at only one point. Even though the bird rests on two feet, both feet are touching the same wire, making them electrically neutral. Electrically speaking, both of the bird's feet touch the same point, so there is no difference in voltage potential between them to induce current flow through the bird's body.

In order for electrons to flow through a conductor, there must be a voltage present to motivate them. Voltage is always relative between two points. There is no such thing as voltage 'on' or 'at' a single point in the circuit, and so the bird contacting a single point in the above circuit has no voltage applied across its body to establish a current through it.

Unlike birds, people are usually standing on the ground or a grounded structure when they contact a 'live' wire. Many times, one side of a power system will be intentionally connected to earth ground, and so the person touching a single wire is actually making contact between two points in the circuit, the wire and earth ground. The presence of an intentional 'grounding' point in an electric circuit is intended to ensure that one side of it is safe to come in contact.

Power circuits usually have a designated point that is 'grounded,' that is, firmly connected to

2

metal rods or plates buried in the dirt. This ensures that one side of the circuit is always at ground potential, that is, at zero voltage between that point and ground.

Figure 21.2 shows the diagram of a circuit moving electric power from a source to the conveyor drive motor. The motor is suitably grounded, so there is no electric shock delivered to a nearby worker.

Figure 21.3 shows the path of the current moving through a worker. When the worker contacts the high-voltage wire—with a wrench, or just by touching the wire—the electric current 'sees' another path to ground.

The typical human body has a contact resistance of approximately 500 ohms at the point of contact with an electrical source. The body has an internal resistance of approximately 100 ohms, and there is another alternating current resistance or impedance to ground of approximately 5,000 ohms.

Rubber-soled shoes provide some electrical insulation to help protect workers from conducting shock current through their feet to ground. However, most common shoe designs are not intended to be intrinsically safe: their soles being too thin and not of the right substance. Also, any moisture, dirt, or conductive salts from body sweat in or on the sole will compromise what little insulating value the shoe has. There are shoes specifically made for dangerous electrical work, as well as thick rubber mats made to stand on while working on live circuits, but these special pieces must be in an absolutely clean, dry condition in order to be effective.

Soil is not a very good conductor, at least not when dry. Dirt is too poor of a conductor to support continuous current for powering a load. However, it takes very little current to injure or kill a human being. Even the poor conductivity of dirt is enough to provide a path for deadly current when there is sufficient voltage available, as there usually is in conveyor power systems. Some ground surfaces are better insulators than others. Asphalt, for instance, being oil-based, has a much greater resistance than most forms of dirt or rock, so standing on asphalt pavement is somewhat safer than bare ground. Concrete, on the other hand, tends to have fairly low resistance due to its intrinsic water and conductive chemical content; therefore, current will pass through it—and someone standing on it—more easily.

As discussed in a 2012 presentation, *Electrical Safety in the Workplace (NFPA 70E)*, written by Bruce Bowman as part of an alliance between OSHA and the Independent Electrical Contractors, Inc. (IEC), the human body, when shocked with certain amount of electricity, has a point where the muscles lock up, and literally 'Cannot Let Go' of the connection to the electric source. This 'Cannot Let Go' level is about 10 milliamps (mA): that is, 10 one-thousandths of an amp. Once muscle

2

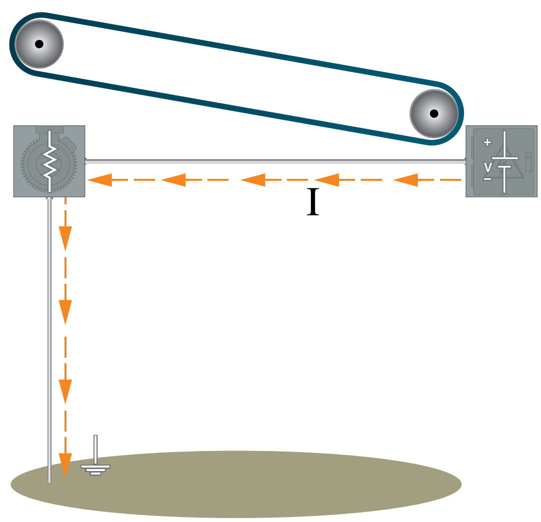


Figure 21.2.

Suitable grounding makes sure the circuit moves the electric current to the conveyor drive.

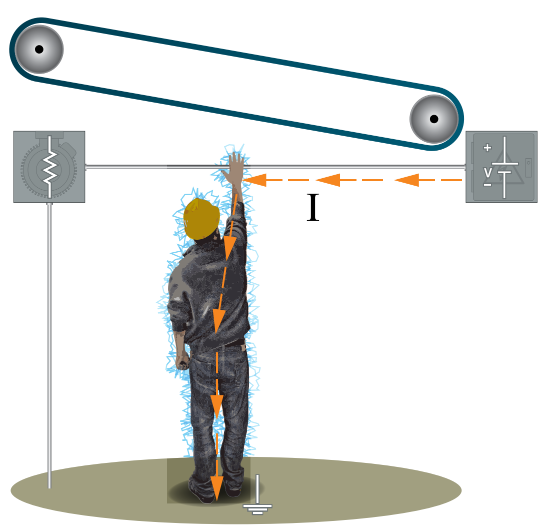


Figure 21.3.

When a worker touches the high-voltage wire, the current finds another path to the ground, shocking the worker.

lock-up occurs, the time in contact with the electric current is likely extended, and the risk of electrocution increases dramatically.

At voltages below 56 volts of alternating current (VAC), it is difficult to generate 10 milliamps (mA) through the human body, so 50 VAC volts is generally considered a safety voltage. The actual safe voltages depend on a variety of factors including a body's resistance, the supply current capacity, the quality of the grounding, and the length of contact time.

Arc Flashes

According to "What is Arc Flash?" an online posting written by Mike Holt on the *National Electric Code Internet Connection*:

> Arc Flash is the result of a rapid release of energy due to an arcing fault between a phase bus bar and another phase bus bar, neutral or a ground. During an arc flash the air is the conductor.

Arc flashes can occur from dirt or foreign material in an electrical box. As electricians work on or near energized conductors or circuits, contact with, or failure of, the equipment may cause a fault. (**Figure 21.4.**) An arc fault is similar to the arc obtained during electric welding.

Mike Holt's web post continues:

> Arc faults are generally limited to systems where the bus voltage is in excess of 120 volts. Lower voltage levels normally will not sustain an arc … and the fault has to be manually started by something creating the path of conduction or a failure such as a breakdown in insulation.

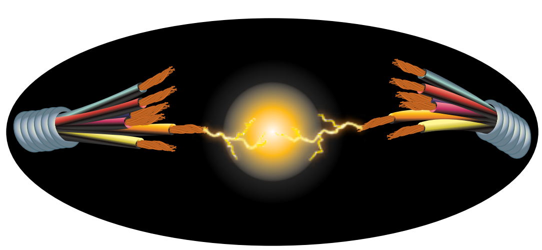


Figure 21.4.

An arc flash is the result of the rapid release of energy due to an arcing fault when the electric current bridges or jumps between two open contacts.

According to an article titled "The Dangers of Arc Flash Incidents" which appeared in the February 2004 edition of *Maintenance Technology* magazine:

> The temperature of an arc can reach more than 5000° F [≈2760°C] as it creates a brilliant flash of light and a loud noise. An enormous amount of concentrated radiant energy explodes outward from the electrical equipment, spreading hot gases, melting metal, causing death or severe radiation burns, and creating pressure waves that can damage hearing or brain function and a flash that can damage eyesight. The fast-moving pressure wave also can send loose material such as pieces of equipment, metal tools, and other objects flying, injuring anyone standing nearby.

The Problems with Magnetic Fields

A great deal of publicity has been focused on the health effects of electromagnetic fields—that is, radio waves—associated with cell phones. Fortunately, most of the issues related to electromagnetic emissions around conveyors have to do with protecting electronic equipment and not their effects on humans. The large motors and power supplies associated with conveyors do generate electromagnetic waves but at frequencies which are well below those identified as creating health risks for humans.

Another form of electromagnetic waves arises from the use of industrial magnets. Both electromagnets and permanent (rare earth) magnets are used in bulk-materials handling to remove tramp metal from the body of material. While the installation point for some magnets is obvious, such as large over-the-belt electromagnetic separators, other installations, such as magnetic grates, magnetic pulleys, and lifting magnets, are less obvious.

There is no material that will block magnetism; magnetic fields will pass through plastic, wood, aluminum, and even lead as if it was not there. Ferrous materials such as iron, steel, or nickel can conduct magnetic fields and redirect magnetism. To remove magnetic forces, steel can be used to provide a shortcut that redirects the magnetism field via an alternative route.

Strong magnetic fields can affect medical devices such as pacemakers causing them to malfunction. Credit cards, computer-storage devices, and other types of magnetic media can be erased by close proximity to strong magnets. Most modern cell phones, computers, and data storage devices no longer depend on magnetic storage but can still be damaged by strong magnetic currents.

There are a variety of recommendations for safe distances from magnets depending upon the strength of the magnet, so it is difficult to specify a single safe distance. Many modern pacemakers have an automatic default function if they sense a strong field. Nonetheless, most magnetic separator manufacturers recommend that no one with a pacemaker be allowed to work in the vicinity of the separator, and that all other workers remove metal and electronic devices from their person when within 50 feet [≈15 m]. (**Figure 21.5.**)

Most accidents occur when workers are either transporting or cleaning the magnet—removing metal from the magnet. The magnets can be instantly and violently attracted to any carbon steel structure, including chutes, pipes, I-beams, or other magnets. If a worker's hands or fingers are caught between the magnet and the carbon steel, the worker can be pinched and possibly seriously injured.

In bulk-materials handling, the release of the tramp iron from magnets can create hazards. Magnetic pulleys often use permanent magnets and depend on the belt movement to be self-cleaning. When the belt moves past a given spot, the magnetic attraction is no longer strong enough to be felt, and so the collected metal falls from the pulley. When power is removed from electromagnets the collected tramp iron will release; this is not always at the intended discharge location. If it misses the collection chute or conveyor discharge hopper, the falling tramp iron could cause injury to unwary workers. Often the collected tramp iron is not considered a form of stored energy that needs to be considered and neutralized in the Lockout / Tagout / Blockout / Testout (LOTO / BOTO) procedure. Warning labels must be placed wherever strong magnets are used.

Static Electricity

According to a *Tech Note #9: State Electricity Considerations* from the National Industrial Belting Association (NIBA), a static charge is generated "when two surfaces in close proximity are moved relative to one another." When dissimilar materials contact each other, sometimes one material may 'borrow' electrons from the other, creating a local voltage difference. When a conducting material comes in contact with this local voltage difference, the voltages will equalize and create a current from one surface to the other. "Conveyor … installations are classic examples. In operation, the belt surface is continually leaving the pulley surface, generating static electricity." The NIBA *Tech Note* continues:

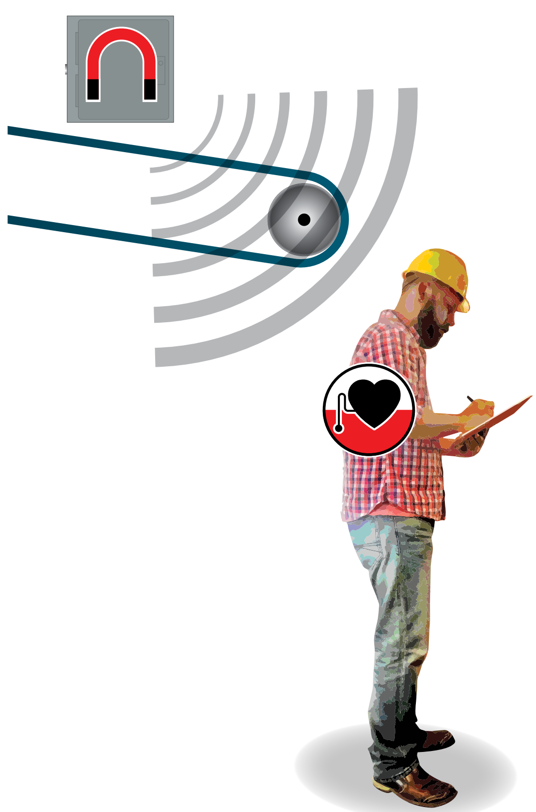


Figure 21.5.

Strong magnetic currents present in some conveyor equipment can affect equipment or personnel.

2

Lightning as an Electrical Hazard

Conveyors are usually large metal objects, often installed outdoors, and often elevated over the surrounding terrain. As such, they are attractive for and susceptible to lightning strikes.

According to monograph *Lightning Safety in the Mining Industry*, by Richard Kithil of the National Lightning Safety Institute (NLSI):

> The phenomenology of lightning flashes to earth, as presently understood, follows an approximate behavior: the downward Leader (gas plasma channel) from a thundercloud pulses toward earth. Ground-based air terminators such as fences, trees … corners of buildings, people, lightning rods, [broadcast towers], power poles etc., emit varying degrees of induced electric activity. They may respond … by forming upward Streamers. In this intensified local field some Leader(s) likely will connect with some Streamer(s). Then, the "switch" is closed and the current flows. Lightning flashes to ground are the result. A series of return strokes follow.

There is a voltage differential between the cloud and the ground. Once a conductive channel bridges the gap between the two locations, a massive electrical discharge follows. This is the 'return stroke,' and it is the most noticeable part of the lightning discharge.

The marketplace offers a variety of lightning detection systems of varying complexity and cost. Users should beware of over-confidence in detection equipment. The detectors are not perfect and do not always acquire all lightning all the time. Detectors cannot predict lightning and cannot help with first-strike, 'bolt from the blue' events.

Perhaps the best detector is human recognition that equates thunder with lightning; hearing thunder indicates the lightning is within one's hearing range and that it is time to seek shelter.

When lightning is detected, the NLSI recommends the following caution categories:

- Yellow Alert–Lightning is 20 to 40 miles (30-60 km) distant. Be cautious.
- Orange Alert–Lightning is 11-19 miles (16-30 km) distant. Be aware.
- Red Alert–Lightning is 0-10 miles (0-16 km). Suspend activities. Go to shelter.

This electric drive motor is poorly bonded to the metal structure, and so poses a hazard if the conveyor was struck by lightning.

For surface mining and processing operations, it is recommended that workers should be within a three to four minute walk of shelter when Red Alerts are announced.

NLSI recommends the following as a lightning safety slogan: "If you can hear it (thunder), clear it (evacuate); if you can see it (lightning), flee it."

Rules of thumb for lightning safety include the following:

- Water and metal objects should be avoided; get off higher elevations including rooftops; avoid solitary trees.
- A large permanent building also can be considered a safe place.
- A fully-enclosed metal vehicle - van, car or truck (with the doors and windows closed) is mostly a safe place because of a quasi-Faraday Cage effect (where lighting flows around the outside of the vehicle and into the ground.) Stay in the vehicle.

NLSI recommends waiting for 20 to 30 minutes to pass from the last observed thunder or lightning before resuming activities.

NLSI offers a variety of safety instruction media for lightning safety; visit lightningsafety.com.

For more discussion of lightning and conveyor safety, **see Chapter 4 Switches and Sensors**.

> The surfaces can be similar, dissimilar, conductive or non-conductive, and static electricity will be generated. … As the conveyor ... continues to operate, the static charge will continue to accumulate and increase unless it is bled off in some manner.

In some applications, such as grain handling, probably the greatest source of static electricity is the sliding of the bulk materials down a chute that has been lined with urethane or UHMW polyethylene. The individual particles of cargo are now charged and will carry that charge onto the conveyor belt where a charge may accumulate.

According to the manual, *The basics of dust-explosion protection*, from R. STAHL Explosion protection GmbH, static discharges takes place in the form of a spark "between grounded and ungrounded components."

A static discharge is able:

> ... to ignite all gases and vapors, and almost all dusts. … Eighty percent of all industrial dusts are combustible, and even a dust layer of 1 mm [≈0.04 in.] in a closed room is sufficient to trigger an explosion when the dust is swirled up and ignited.

R. STAHL statistics indicate static electricity is the ignition source of nine percent of industrial dust explosions.

Guidelines for the Control of Static Electricity in Industry, published by the New Zealand's Occupational Safety & Health Service, Department of Labour, adds:

> Additional hazards [from static electricity] are the production of unexpected shocks in humans that might result in injury caused by involuntary reflex action, and the possibility that false readings will be induced in sensitive instruments where static is present. These hazards may be less significant when compared with the ignition problem but they should still be given consideration.

The effects of static electricity stem from the voltage accumulated, a subsequent electrostatic discharge resulting in an electromagnetic pulse, and discharge current.

Making the entire system sufficiently conductive and properly grounded can control the accumulation and storage of static electricity. This means that the belt, pulley lagging, pulley, bearing, structure, and electrical ground must all be connected electrically. It also means that conductive grease would be essential in the bearings.

According to the NIBA *Tech Note #9 notes:*

> Extensive studies by the British National Coal Board (1950-1966) … found that belts with a surface electrical resistance of 1×10^9 ohms or less did not retain a static charge when run on a typical grounded conveyor. While those [belts] with a surface electrical resistance of 6×10^9 ohms and greater did retain static charges. As a result of this work, the B.N.C.B. concluded that a maximum of 3×10^8 resistance was a safe condition in new conveyor belts in underground coal mines.

Accordingly, any belt with a surface resistivity of 300 megaohms (300×10^6 ohms) or less is said to be static conductive. (**See Chapter 15 Conveyors, Belting and Fires.**)

For installations where static creates a safety hazard or production issue—where material clings to the belt—specially formulated rubber covers are available from all major belt manufacturers.

Maintenance Work and Electricity

Maintenance personnel can be exposed to many electrical hazards. Even with the use of Lockout / Tagout / Blockout / Testout (LOTO / BOTO) procedures there may be energized wires or structures. Because of the numbers of electrical components or poor maintenance practice, there is always a chance of electrical current being 'back-fed' into the area or equipment where work is being done. The best way to protect maintenance workers is to have an electrician inspect and test circuits in the area before work begins.

Too often, inadequate maintenance practices allow poor conditions for the electrical supply and system components on and around conveyors. These poor conditions put maintenance and cleanup workers at risk. (**Figure 21.6.**)

The following are some electrical safety issues to be conscious of when working around belt conveyors:

- Water (or damp conditions) when working around electricity.
- Cables on the ground; wires and cables in poor condition.
- Open electrical enclosures, junction boxes, uncovered outlets, and disconnected conduit, all of which expose wires and connections to environmental conditions and the stress of movement.
- Conduit that is poorly located in regard to other components. The need to access the other components will put poorly placed conduit and/or a worker in jeopardy.
- 'Jumping over' (bypassing) control or safety devices, to reduce nuisance 'trips.'

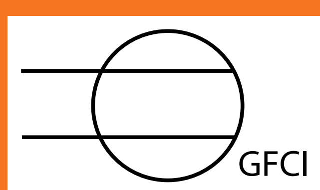
Many of these problems can be identified and corrected through proper and on-going inspection and maintenance practices.

Figure 21.6.

Poor conditions or inadequate maintenance can allow electrical equipment to pose a hazard.

The use of defective power tools and worn or damaged extension cords expose the worker to potential shock and electrocution hazards. Power tools should be double insulated to reduce the chance of creating a path for current to flow should the tool contact a live wire. Power tools, extension cords, portable lighting, fans, and other electrically powered equipment used during maintenance should be inspected regularly for proper grounding and damage. Defective tools should be immediately taken out of service, repaired, or discarded.

Ground Fault Interruption



An accidental connection between a power-system conductor and ground is called a ground fault. Ground faults may be caused by many things, including dirt buildup on power line insulators—creating a dirty-water path for current from the conductor to the pole and to the ground when it rains—and ground water infiltration in buried power line conductors. Given the varied causes of ground faults, they tend to be unpredictable.

A Ground Fault Current Interrupter (GFCI) protects against electrocution. A GFCI works by measuring the difference in current between the 'live' or 'hot' wire and the other side. If the currents are not equal, then some of the current must be leaking in an unwanted way, and the GFCI shuts off the power. After the problem is fixed, the device must be reset manually with a reset button. A typical GFCI has a test button next to its reset control; the GCFI should be tested at least once a month and a record kept.

GFCIs protect just that outlet, or a series of outlets that are connected to the GFCI. A GFCI Circuit Breaker can be installed on some electrical panels to protect an entire branch circuit. Portable in-line plug-in GFCIs can be plugged into wall outlets where maintenance tools will be used. A painful, if non-fatal, shock may occur during the time that it takes for the GFCI to cut off the electricity, so it is important to use the GFCI as an extra protective measure rather than as a replacement for safe work practices.

Electrical Hazards from Welding

Welding is a common conveyor maintenance activity that exposes workers to the possibility of electric shock. Electric shock occurs when a welder touches two metal objects that have a voltage between them, thereby inserting the worker into the electrical circuit. For instance, if a worker holds a bare wire in one hand and a second bare wire with the other hand, electric current will move from one wire to the other by passing through the welding operator on the way, causing the operator to sense an electric shock. The higher the current, the higher the risk for injury or death.

The article, *Be Prepared: Five Potential Welding Safety Hazards to Avoid*, by John Petkovsek, Director, Environment, Health and Safety, The Lincoln Electric Company states:

> Due to its constant change in polarity, alternating current (AC) voltage is more likely to stop the heart than direct current (DC) welders. It is also more likely to make the person holding the wire be unable to let go.

The article continues with the note:

> … Welding operators should wear dry gloves in good condition, never touch the electrode or metal parts of the electrode holder with skin or wet clothing and be sure to insulate themselves from the work and ground.

REGULATIONS AND STANDARDS

Every major country has a law(s) related to electrical safety that authorizes the development of specific standards and regulations. The standards and regulations are designed to improve all aspects of electrical safety. There is both commonality and differences in electrical safety standards and regulations from country to country.

In the United States, the general authorization for implementing electrical safety regulations is defined in both the *Occupational Safety and Health Act of 1970* (OSHA) and the *Federal Mine Safety and Health Act of 1977* (MSHA). In Canada, the operative by law is the *Safety Standards Act [SBC 2003], Chapter 39*. In Australia, the *National Electricity (South Australia) Act 1996* has been adopted by the other participating states in the Commonwealth. In the EU, *Directive 2006/95/EC – electrical equipment* establishes the basis for national laws related to most voltages. In Brazil, the law is *NR-10 Safety in Electrical Installations and Services*.

2

Safety Tips for Power Tools

Maintenance workers will often be required to use power tools operated by electricity. Here are some best practices for safety when using power tools.

- Use battery-powered hand tools whenever possible.
- Switch all tools OFF before connecting them to a power supply.
- Disconnect and lock out the conveyor and component's power supply before completing any maintenance work tasks.
- Ensure tools are properly grounded or double insulated. Grounded equipment must have an approved 3-wire cord with a 3-prong plug. This plug should be plugged in a properly grounded 3-pole outlet.
- Test all tools periodically for effective grounding and keep a record.
- Do not bypass the ON/OFF switch do not operate the tools by connecting and disconnecting the power cord.
- Do not use electrical equipment in wet conditions or damp locations unless the equipment is connected to a GFCI. Always test the GFCI before beginning work.
- Do not clean tools with flammable or toxic solvents.
- Do not operate tools in an area containing explosive vapors or gases, unless they are intrinsically safe and only if you follow the manufacturer's guidelines.
- Keep power cords clear of tools during use.

A typical requirement might read:

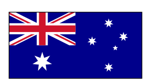
> Conveyor electrical equipment must conform to the (applicable jurisdiction's) Electrical Code. Such equipment includes materials, accessories, devices, appliances, fasteners and other equipment used in the electrical power supply of a conveyor or in connection with a conveyor, including power disconnect devices.

In general, work standards around the world are compatible with those requirements issued by the Mine Safety and Health Administration (MSHA) in the United States. The MSHA standards (in *30 CFR 56/57.1–2006, 56/57.12016,* and *56/57.12017*) require that before working on electrical circuits the power be disconnected, switches locked out, and warning notices be signed and posted.

In addition, there are often specific regulations for electrical safety for certain industries—such as underground mining—or for types of equipment such as conveyors. These regulations often require specialized wiring practices and safe design of components for hazardous environments such as the explosive dusts present in grain handling.

The standards and regulations typically focus on the qualifications for electricians, product conformance with electrical standards, and proper wiring methods for various applications and levels of voltage and current. Often there are different regulations for mining and general industry. The trend is to include in the regulations' electrical codes and various standards by reference. Generally, the standards and regulations are technical in nature and intended for use by qualified electricians and electrical engineers.

Some of the common electrical codes and standards include:



Australia

AS/NZS 3000:2007 Electrical installations (the Wiring Rules)

AS/NZS 3017:2007 Electrical installations – Verification guidelines

AS/NZS 3760:2010 In-service safety inspection and testing of electrical equipment

Brazil

NR-10 Safety in Electrical Installations and Services

Safety Tips for Power Cords

Extension cords will allow workers to use electrical equipment in remote locations. The following are tips for working with power cords.

- Use extension cords only to temporarily supply power to an area that does not have a power outlet.
- Inspect portable cord-and-plug connected equipment, extension cords, power bars, and electrical fittings for damage or wear before each use.
- Suspend extension cords temporarily during use over aisles or work areas to eliminate stumbling or tripping hazards.
- Always tape extension cords to walls or floors when necessary. Do not use nails or staples as they can damage extension cords causing fire and shock hazards.
- Use extension cords or equipment that is rated for the level of amperage or wattage in use.
- Replace open front plugs with dead front plugs. Dead front plugs are sealed and present less danger of shock or short circuit.
- Do not use light-duty extension cords in a non-residential situation.
- Do not carry or lift electrical equipment by the power cord.
- Do not tie cords in tight knots. Knots can cause short circuits and shocks. Loop the cords or use a twist-lock plug.
- Replace broken 3-prong plugs and make sure the third prong is properly grounded.
- Keep extension cords away from heat, water, and oil. They can damage the insulation and cause a shock.
- Do not allow vehicles to pass over unprotected extension cords. Extension cords should be put in protective wire way, conduit, or pipe or be protected by placing planks alongside them.

Canada

CSA C22.1-15 Canadian Electrical Code Part 1 (23rd Edition) safety standard for electrical installations

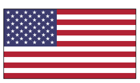
CSA Z462-15 Workplace Electrical Safety

China

DL 408-1991 Safety code of electric power industry – Electrical part of power plants and transformer substations

Europe

BS EN 50110-1:2013 Operation of electrical installations. General requirements



United States

National Electrical Safety Code® (NESC®)

NESC is developed and maintained by the Institute of Electrical and Electronics Engineers (IEEE). NESC is now used in over 100 countries as the basis for their electrical safety regulations.

NFPA 70: National Electrical Code® (NEC®).

NFPA 70E: Standard for Electrical Safety in the Workplace®
NFPA 70 and *NFPA 70E* are published by National Fire Prevention Association (NFPA).

BEST PRACTICES
Working With or Near Electricity

These best practices are intended for the non-electrician who must work on or around conveyors and other electrical systems. Do not work on any equipment unless a qualified electrician has checked and de-energized the equipment and/or wiring. (**Figure 21.7.**)

Daily examination of conveyor systems must include more than just their mechanical components; it must also include the condition and performance of the cables and drive, as well as other electrical controls and components.

Before performing electrical work, a worker should:

- Be trained on all the electrical tests and safety equipment necessary to safely test and ground the circuit being worked on.
- Conduct a risk assessment.
- When necesary, use the properly rated additional electrical personal protective equipment as instructed by an electrician.
- Positively identify the circuit on which work is to be conducted.
- De-energize power and ensure that the circuit is visibly open.
- Lock out and tag out the disconnecting device.
- Request verificaton by an electrician that the circuit is de-energized.
- Do not work on components inside electrical enclosures.
- Request an electrician to ground all phase conductors when working on or around multi-phase supplied equipment.

Figure 21.7.

Before working on any electrical system, the system should be de-energized, including a lockout / tagout procedure.

- Use the right equipment for the job, including insulated tools.
- Know the location of the nearest Automated External Defibrillator (AED), to allow for quick use if required. (**Figure 21.8.**)

Figure 21.8.

It is a good practice to know the location of an automatic external defibrillator (AED) before working on electrical systems.

CLOSING THOUGHTS
Insulating Yourself from Danger

Electrical injuries represent a serious workplace health and safety issue. The need for workers to work on or around belt conveyors—in most, if not all, cases powered by electric drives and connected to other electrical components, sensors, and systems—means that workers are at risk. There must be training and precautions in place to provide for the safety of those workers.

Education is the essential tool for the safety of plant employees and contractors. Safety around electrical systems should be a part of the initial induction, 'sign on,' or 'onboarding' training process for all workers, especially those who will regularly work on or around belt conveyors. It should also be a frequent topic for the regular 'toolbox' or 'tailgate' safety briefings. ⚠

Section 3 SAFE WORK PRACTICES

Chapter 22 Man-Riding Conveyors

INTRODUCTION
Riding on the Belt

The practice of riding a conveyor belt into and out of mines has a long history in mining but updated regulations regarding safe practices only began to appear in the 1990s. The practice is called man-riding.

Man-riding conveyors often require a more stringent set of rules than short in-plant or overland conveyors, as they can carry people as well as material on either the carrying or return strand. They are normally found in mines and are inclined to transport workers in and out, as well as carry crushed material out in the normal way. (**Figure 22.1.**)

The rationale and some of the considerations for this practice are explained in section 603 (1) of Part 36 Mining of the Canadian Province of Alberta's *Occupational Health and Safety Code 2009 Explanation Guide*:

> Working areas in underground coal mines are sometimes a great distance

3

from the surface and walking conditions can be poor. In some underground mines, workers ride on specially designed conveyor belt systems to get to and from their respective work areas. In such cases, the entire system must be specifically designed and certified by a professional engineer.

This system includes provisions for getting on and off the moving conveyor and worker training to use the system. The system must also include various fail-safe protective measures to prevent incidents, e.g. if workers cannot get off the belt as anticipated, a method of stopping the belt before the worker is endangered must be incorporated.

The transcript of a 1978 symposium, *Underground Transport in Coal Mines,* noted there were then "some thousands of manriding installations in Europe." However, the practice of riding on conveyor belts to transport people into and out of mines is seen less today because of the higher belt speeds of conveyors and the development of safer means of personnel transport. However, man-riding is still practiced at a number of underground mines around the world including locations in Germany, Turkey, and South Africa.

Justifications for Man-Riding Conveyors

The reasons for employing a man-riding system are usually concerned with the prompt and timely arrival of workers at their stations without undue delay or trouble; in this case, trouble would include added expense. Typically, justifications for the use of conveyor man-riding practices appear to be confirmations of the financial justification rather than an analysis of safety and consequences.

For example, the 1989 Beltcon 5 paper, *The Planning of an Underground Manriding Conveyor System for Iscor's Tshikondeni Colliery*, by W. Moller and E.R. Ascui explained in its introduction:

> Safety, economic and operating factors have forced Iscor to look closely at the different means of transporting personnel underground at Tshikondeni mine, where the rapid advancing of the fully mechanized faces have resulted in increased travelling time for underground personnel, thus decreasing the available time at the face. The machine available time (MAT) will gradually be eroded further unless personnel transport is improved to limit the travelling time.

3

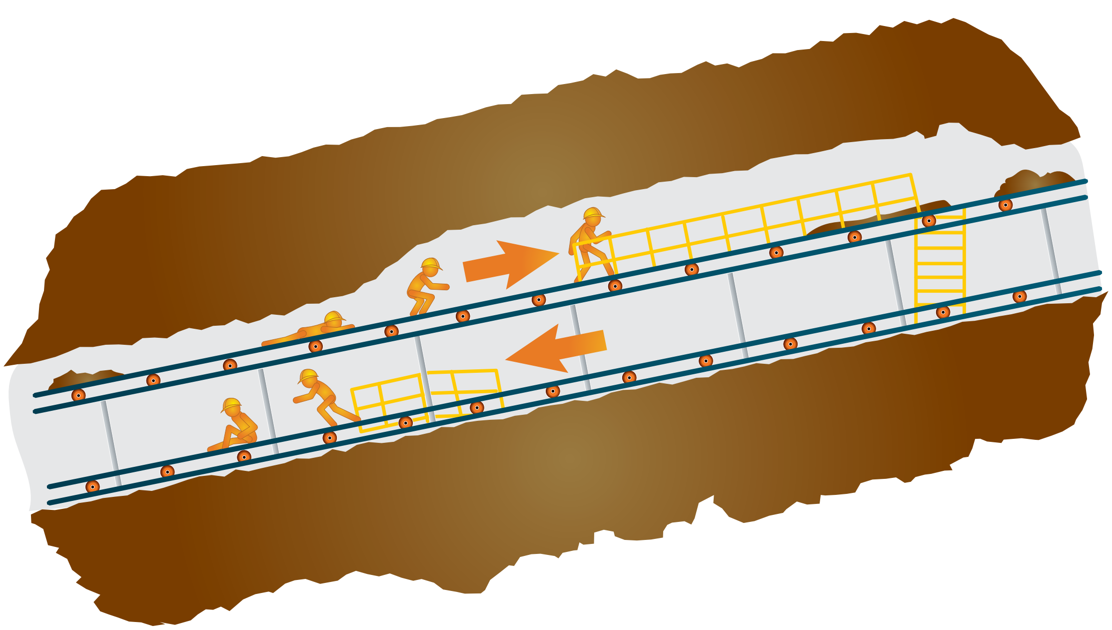


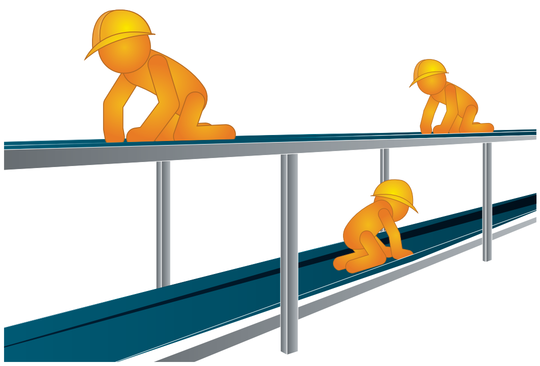
Figure 22.1.

Man-riding conveyors are used in mines to transport workers to and from the working face.

The advantages to be gained from speedy and comfortable personnel transport are obvious, and there can be no doubt that such systems can result only in improved productivity because of increased MAT and fresher workers.

Figure 22.2.

Riding on a belt conveyor can be a challenging or even unpleasant experience.



The Challenges of Man-Riding

Some workers consider riding the belt to be more comfortable than riding in a mantrip or motorized vehicle along the conveyor path. Other workers will confess to using a conveyor as a taxi or shuttle, riding belts that are neither authorized nor designed for man-riding. (**Figure 22.2.**)

But as many riders will attest, riding on a conveyor belt is not entirely a pleasant experience; it is not a trip to the amusement park. Safely riding on a mine conveyor belt poses some challenges. These challenges are multiplied with the necessary tasks of boarding and exiting from the belt.

Miners are wearing the common personal protective equipment, plus headlamp, battery,

UK Agency Issues Safety Alerts for Man-Riding Conveyors

The United Kingdom's Health and Safety Executive (HSE) has published a *Safety Alert* on man-riding conveyors. This *Alert* concerned incidents where a worker on a man-riding conveyor passed under the safety gate at the discharge point (alighting platform). Installed to prevent such a passage, the safety gate was mounted just over 500 millimeters [≈20 in.] above the center of the conveyor.

The HSE *Safety Alert* noted this position allows lumps of mined material:

> ... to pass through without activating the gate, but this is easily high enough to allow a person riding in a prone position to pass beneath it without causing it to operate.

The *Safety Alert* noted a similar incident in 1992 when another experienced miner failed to alight from a man-riding conveyor, passed beneath a safety gate, and was killed. The *Alert* noted:

> There is clearly an increased risk to persons riding conveyors where a safety gate is set high to allow the unimpeded passage of minerals to the extent that it will also allow a person in a prone position to pass beneath it without operating.

The *Alert* continued:

> Mine managers and engineers must therefore ensure that they do all that is reasonably practicable to provide an effective means of stopping any man-riding conveyor, whether or not it is also used for conveying minerals, in the event of someone overshooting an alighting platform and remaining in a prone position on the belt.

A second alert was issued by the HSE when, following a maintenance procedure, a conveyor was inadvertently left set to operate in the reverse direction. A worker who had boarded the stationary conveyor and was sitting on the belt sustained injuries when the conveyor was started in a reverse direction. This *Safety Alert* noted:

> The risk of a person being drawn backwards into in line boarding platforms, or into equipment suspended over man riding conveyor belts, or into areas of converging clearance, or tail ends of conveyors, and the effect of gradients, must all be taken into account.

The *Safety Alert* concluded:

> When a man riding conveyor needs to be operated in reverse strict management control measures must be in place to ensure that it is returned to its correct direction of operation prior to man riding again being allowed.

self-rescuer, radio, tools, and often carrying a lunch pail or backpack. The rider may share the belt with conveyor cargo, or at minimum, the residual carryback on the belt.

Riding at belt speed through lengthy, darkened, confined passages, with low overheads and short distances to walls is likely to be uncomfortable and even frightening. Even when the belt speed is moderate, the journey can be disorienting or disconcerting.

Some man-riding conveyors are ridden seated; others are ridden while lying down in a face-down or face-up position. The required position may depend on the overhead clearances along the belt path, or the amount of cargo and/or carryback on the belt.

While it may save time and the energy of the worker by reducing the effort required to get to where the work needs to be done, man-riding is not by nature a safe and easy trip.

The Hazards of Man-Riding Conveyors

The use of man-riding conveyors poses a number of hazards. These hazards are related to safely getting on and off the belt, the risks from damaged or broken belts, and of the dynamics of the belt. Accident reports describe loose clothing getting caught in nip points, belt failures causing a pile of bodies at the bottom of the conveyor, failures to get off the belt at the appropriate location, and failures of the emergency-stop system. The dynamics of stopping and starting wide, fast conveyor systems or sudden changes in belt sag from missing idlers can send transient waves through the belt tossing workers off the belt.

The 2001 report, *Best Practice: Conveyor Belt Systems*, prepared for the Safety in Mines Research Advisory Committee in South Africa [*SIMRAC Report*] includes best practices applicable to both material-carrying and man-riding conveyors, as well as a section devoted exclusively to best practices for man-riding conveyors.

Riding with material—a fairly common practice on man-riding conveyors—can be a problem. The *SIMRAC Report* notes in section 8.2.5:

> The danger involved is that the worker may get injured during boarding or alighting while attempting to ride the conveyor while there is material on the belt. The biggest danger is that workers may stumble over material or may slip on loose material on the belt during alighting.

In the United Kingdom, the Health and Safety Executive's 1993 *Topic Report: Safe use of belt conveyors in mines* [*HSE Topic Report*] also discussed man-riding conveyors, noting that riding "on mineral carrying conveyors may give rise to particular hazards."

The *HSE Topic Report* continues by saying that the design of the system and the rules for its operations should ensure that:

(a) the bed of mineral does not result in unacceptable clearances;

(b) boarding, lying on and alighting off mineral can be done safely;

(c) mineral does not roll down inclined conveyors;

(d) airborne dust does not affect visibility;

(e) clearances are such as to obviate the possibility of a blockage occurring.

Another hazard cited in the *SIMRAC Report* was the possibility of water on the belt. Section 8.2.8 says:

> In a man-riding environment any water on the belt should be avoided. The belt construction is such that the belt will become slippery when wet. Care and training to keep the belt dry should be encouraged amongst the workers. If there is a possibility that the belt may be wet, workers should not be allowed to board since they may slip and fall resulting in severe injury or death.

Another hazard of man-riding conveyors is they have a hypnotic effect derived from the rhythmic, low-frequency movement over the idlers. As a result, it is not unusual for workers to fall asleep when riding a belt. The *SIMRAC Report* notes in section 8.2.6:

> Workers falling asleep on the belt during transportation and failing to alight is a significant danger associated with man-riding conveyors. Workers sleeping on the belt and passing the detection systems may result in the worker being discharged into the chute causing severe injury and probably death.

Perhaps the greatest hazard from allowing riding on the belt is its tendency to encourage workers to feel safe when standing, crossing, riding, or sleeping on the belt.

Considerations for the Design of Man-Riding Conveyors

Due to the risks cited above, the safety requirements and specifications for man-riding conveyors are more tightly controlled than those for materials-only belt conveyor systems.

Illegal Man-Riding

While man-riding itself offers a number of hazards, what is more dangerous is 'illegal' man-riding, that is riding on a belt in a facility where the conveyors are not intended for this practice. This is because those types of conveyor systems are not designed to accommodate personnel transport, and the workforce has not been properly trained.

Statistics in the *HSE Topic Report* show that of conveyor accidents recorded in the five-year period from 1986 through 1991, most man-riding fatalities—and indeed the majority of conveyor fatalities in total—were attributed to illegal man-riding. Of the eight conveyor fatalities, five were caused by illegal man-riding, while another man-riding fatality was ascribed to a breach of management's transport rules while riding. (**See Table.**) The report noted that 29 percent of total conveyor accidents were man-riding accidents, including 6 deaths and 57 major injuries.

The report notes that conveyors not expressly designed to allow man-riding "do not have safe means for boarding and alighting or other necessary manriding safeguards and frequently do not have adequate clearances for manriding."

The *HSE Topic Report* states,

> The tragic accidents referred to in this category will only be eliminated if persons resist the temptation to ride on conveyors not authorised for manriding and if all mine officials rigorously enforce managers' transport rules.

Conveyor Accidents by Category
1986-87 to 1990-91

Category	Fatal	Major Injury	Lost Time Over Three Days
Man-Riding: Accidents			
Man-riding: poor installation or failure to mantain standards.	–	7	52
Man-riding: breach of managers' transport rules	1	19	46
Man-riding: apparent lack of normal causation	–	9	154
Man-riding: illegal	5	22	3
Non-Man-Riding Accidents – use, installation, and maintenance			
Inadequate clearances or guards	–	11	27
Maintenance, on or around moving or stalled conveyors	–	25	118
Maintenance, on or around stationary conveyors	1	15	262
Misuse of equipment	–	12	36
Blocked chutes, falling spillage	–	8	97
Use of conveyor as working platform	–	6	55
Use of conveyor to transport materials	1	–	32
Struck or fell while crossing conveyor	–	–	57
Total Accidents	**8**	**134**	**939**

Source: *HSE Topic Report*

The specifications of the conveyor for belt width and speed must be carefully considered. The *HSE Topic Report* specifies:

> Manriding speeds do not usually exceed the 2.67 m/s [≈526 fpm] stated in British Coal codes and rules. For conveyor speeds in excess of this, special consideration should be given to the width of the conveyor to aid safe boarding and to the vertical clearances throughout the manriding length, especially at boarding and alighting platforms. It is recommend that the nominal width of such conveyors should not be less than 1.05 m [≈41.5 in.] and vertical clearances at boarding and alighting stations should not be less than 1.8 m [≈71 in.]. … Manriding should not be allowed at speeds in excess of 3 m/s [≈591 fpm] unless a safe method can be provided for boarding and alighting from the conveyor. The conventional practice of stepping onto and off a conveyor belt is not considered safe at speeds faster than 3 m/s [≈591 fpm].

The requirements for controls for man-riding conveyors are far more stringent than normal conveyor controls because people are being transported on the belt. Smooth starting and stopping even under an unbalanced load is essential to keep workers on the belt and safe.

It is essential that pull-rope safety switches be provided and positioned so that all riders can easily and safely operate them.

A safety device at the unloading points should be provided for stopping the belt should a person not exit at the appropriate station. The stopping (coasting) distance of the belt should be such that a worker who misses the unloading point and then pulls the stop cord does not reach the discharge point. (**Figure 22.3.**)

Perhaps obviously, it should be further emphasized that no conveyor that delivers into a crusher or bunker should be authorized for man-riding.

It is imperative that the belt never lifts off the idlers as this could crush a worker against either the conveyor structure, enclosures, or the walls on either side.

Effective crowd control should be provided to maintain spacing and safe loading practices when large numbers of persons will be man-riding, such as at shift change times.

The standards provide some guidance on the clearance distances from structures and other obstructions and the distance between riders.

In 1984, British Coal Corporation issued *Codes and Rules CR/13 – Underground Belt Conveyors* which included specifications for belt conveyors used for man-riding. These specifications defined standards for clearances, belt speeds, boarding and alighting stations, and safety devices.

These British Coal Corporation rules for man-riding conveyors are included as an appendix in the book, *Belt conveying of minerals*, by E.D. Yardley and L.R Stace, published in 2008 by Woodhead Publishing Limited, Cambridge, England.

The Beltcon 5 paper, *The Planning of an Underground Manriding Conveyor System for Iscor's Tshikondeni Colliery*, included a lengthy addendum, "Manriding Conveyors for Underground Mine Use Proposed Standard Based on International Standards." Topics discussed in this appendix include:

- Limitations of Use
- Conveyor Speed and Gradients
- Clearances
- Boarding and Alighting Stations
- Requirements for the Belting

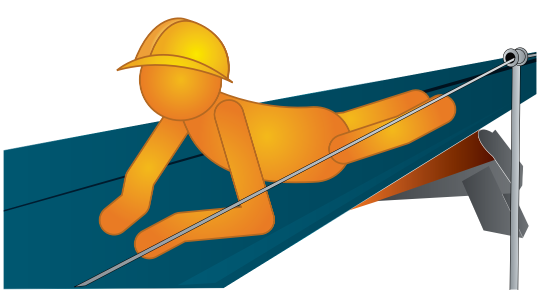


Figure 22.3.

Pull-rope emergency-stop switches should be positioned so that riders can easily and safely operate them.

3

- Safety Devices
- Communication Systems
- Illumination
- Signage and Notices
- Required Inspections (Daily and Weekly)
- Training for Personnel

These proposed standards were based on the British National Coal Board *Codes and Rules CR/13 – Underground Belt Conveyors* as well as German recommendations for personnel transport by belt conveyor.

REGULATIONS AND STANDARDS

Australia

In its section 3.7, the 2015 Australian/New Zealand standard *AS/NZS 4024.3611 Conveyors – Belt conveyors for bulk materials handling* forbids bulk-materials-handling belt conveyors to be used for personnel transport, except where there is no alternative means of emergency egress.

The standard continues that if the conveyor is to be used for emergency egress, it needs to be designed for that purpose. A design risk assessment must be performed to reduce hazards at the loading, transfer, and unloading of people. Considerations in this risk assessment include provision of a method to transfer the belt to person-riding mode, a method to make sure a rider can stop the belt, and a belt speed that is slow enough for rider safety. It should also assess the risks of carrying idler nip points and of interference with roof, mine rib, and structures, the methods for loading and unloading, and the training of personnel.

Canada

Alberta's *Occupational Health and Safety Code – 2009* goes into detail as to the requirements for a man-riding conveyor in section 603. The specifications include:

> 603(1)
> A worker must not ride on a conveyor belt unless the conveyor installation is certified by a professional engineer and designated by the employer as a riding conveyor belt.
>
> 603(2)
> An employer must ensure that a conveyor designated as a riding conveyor belt complies with the following:
>
> (a) it is at no place steeper than 15 degrees from the horizontal plane;
>
> (b) it has head room clearance along its entire length of at least 0.9 metres [≈36 in.];
>
> (c) it has a maximum belt speed of 2.65 metres per second [≈520 fpm];
>
> (d) it has a belt width of not less than 915 millimetres [≈3 ft];
>
> (e) it has mounting platforms with non-slip surfaces that
>
> (i) are not less than 1.5 metres [≈ 5 ft] long and 0.6 metres [≈24 in.] wide, and
>
> (ii) have a clearance of 2.4 metres [≈8 ft] above the platform for the length of the platform plus 10 meters [≈33 ft] beyond the platform in the direction the belt travels;

Training for Man-Riding Safety

The *SIMRAC Report* offered some thoughts on the training requirements for the safe and successful use of man-riding conveyors. In section 8.2.1 the report specifies:

> Every installation where man-riding belts are installed must have a training facility where visitors and new employees can undergo training by a skilled training officer, before going onto the actual man-riding conveyor. This training facility should preferably be on an incline and must allow for riding both carry and return strand. The training conveyor should also be variable speed, allowing trainees to at first board and alight at a slower speed ... The more accurately the training facility simulates the actual environment i.e. belt speed, station layout et cetera, the more the benefit to be reaped from it.

(f) it has dismounting platforms with non-slip surfaces that

(i) are not less than 1.5 metres [≈5 ft] long and 0.6 metres [≈24 in.] wide,

(ii) are fitted with a handrail, and

(iii) have adequate head room clearance to allow workers to dismount without stooping;

(g) the mounting and dismounting platforms are electrically illuminated;

(h) it has reflective signs that clearly indicate

(i) the mounting platforms,

(ii) the dismounting platforms, and

(iii) the approaches to dismounting platforms at 30 metres [≈100 ft], 20 metres [≈67 ft] and 10 metres [≈33 ft] from the dismounting place;

(i) it has a safety device that automatically stops the belt if a worker travels beyond the dismounting platform;

(j) it has automatic brakes that apply when the belt is stopping; and

(k) it has a safety device that automatically stops the belt if a tear or split in the belt is detected.

603(3)
An employer must develop safe operating procedures for workers who are required to travel on a riding conveyor belt.

603(4)
An employer must post the safe operating procedures for a riding conveyor belt in conspicuous and appropriate locations.

South Africa

The *South African Mine Health and Safety Act, (Act No. 29) of 1996 as amended through April, 2015,* specifies:

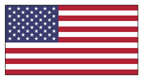
8.9(7)
The employer must take reasonably practicable measures to ensure that the use, operation and inspection of man-riding conveyors comply with *SANS 10266: 2006 – Edition 1 The safe use, operation and inspection of man-riding belt conveyors in mines.*

SANS 10266-2006 superseded the previous standard *SABS 0266: 1995 Code of Practice, The Safe Use, Operation and Inspection of Man-riding Belt Conveyors in Mines.*

The 1995 paper, *An Overview of the Installation Of the First Man-Riding Belt Conveyor in a South African Gold Mine*, presented at Beltcon 09 by C.P. Hughes, provides a list of the requirements in that earlier *SABS 0266* standard; the following is a review of the topics covered:

- Boarding and alighting platforms.
- Safety barriers at boarding and alighting platforms.
- Special stringer arrangement at lower belt alighting platform.
- Additional clearance above belts.
- Some additional slipping of the hanging wall and sidewall around the platform areas, to provide adequate clearances for riders.
- A 'man plough' before the tail pulley.
- An additional trip wire along the length of the conveyor.
- A brake to prevent runaway, and to stop within 9 m [30 ft].
- Audio communication at each pull key [pull-rope stop switch].
- Belt-slip detectors.
- Belt-rip detectors.
- Belt training idlers near platforms, and other areas as required.
- Belt misalignment detectors.
- 'Over-travel' trips beyond each alighting platform.
- 'Wake-up' chains across belt at alighting platform.

- Chute blockage trips.
- Additional lights, alarms, signals, and notices at boarding and alighting platforms.
- 10-degree V-return idlers, spaced at 2 m [≈79 in.] intervals, instead of flat rolls.
- Intermediate ladders for disembarkation from the top belt after a stoppage.



United States

While there is little (authorized) use of man-riding conveyors in the United States, Mine Safety and Health Administration (MSHA) regulations allow man-riding on properly equipped conveyors in underground coal mines. MSHA's Hoisting and Mantrip regulations in *30 CFR 75.1403-5* specify the following:

(a) Positive-acting stop controls shall be installed along all belt conveyors used to transport men, and such controls should be readily accessible and maintained so that the belt can be stopped or started at any location.

(b) Belt conveyors used for regularly scheduled mantrips should be stopped while men are loading or unloading.

(c) All belt conveyors used for the transportation of persons should have a minimum vertical clearance of 18 inches [≈457 mm] from the nearest overhead projection when measured from the edge of the belt and there should be at least 36 inches [≈914 mm] of side clearance where men board or leave such belt conveyors.

(d) When men are being transported on regularly scheduled mantrips on belt conveyors the belt speed should not exceed 300 feet per minute [≈1.5 m/s] where the vertical clearance is less than 24 inches [≈610 mm], and should not exceed 350 feet per minute [≈1.8 m/s] when the vertical clearance is 24 inches [≈610 mm] or more.

(e) Adequate illumination including colored lights or reflective signs should be installed at all loading and unloading stations. Such colored lights and reflective signs should be so located as to be observable to all persons riding the belt conveyor.

(f) After supplies have been transported on belt conveyors such belts should be examined for unsafe conditions prior to the transportation of men on regularly scheduled mantrips, and belt conveyors should be clear before men are transported.

(g) A clear travelway at least 24 inches [≈610 mm] wide should be provided on both sides of all belt conveyors installed after March 30, 1970. Where roof supports are installed within 24 inches [≈610 mm] of a belt conveyor, a clear travelway at least 24 inches [≈610 mm] wide should be provided on the side of such support farthest from the conveyor.

(i) Telephone or other suitable communications should be provided at points where men or supplies are regularly loaded on or unloaded from the belt conveyors.

MSHA regulations also note in *30 CFR 56.9200 Transporting Persons* that, "Persons shall not be transported— ...

(h) On conveyors unless the conveyors are designed to provide for their safe transportation.

United States standard *ASME B20.1-2009 Safety Standard for Conveyors and Related Equipment* prohibits riding on most types of conveyors. In section 5.12 Operation it says:

(d) No person shall ride on a conveyor, except on a slow-moving assembly conveyor 0.4 m/s (80 ft/min) maximum or on a conveyor that incorporates a station specifically designed for operating personnel.

BEST PRACTICES
Safety for Man-Riding Conveyors

While the existence of standards for the design of man-riding belts indicates general acceptance of this transportation technique in the industry, serious and fatal accidents still occur from this practice. (**Figure 22.4.**)

- Authorized riding on a conveyor belt is a practice that should be discouraged and discontinued.
- Unauthorized man-riding should be discouraged in training, counseled against when observed, and when repeated, punished up to and including termination of employment.

In the event that man-riding is an authorized and accepted practice, specific engineering considerations should be observed. They include:

- No conveyor used for man-riding should deliver into a crusher or bunker.
- It is essential that pull-rope emergency-stop switches are provided and positioned so that all riders can easily and safely operate them.
- Effective crowd control should be provided when large numbers of workers are riding or preparing to board, especially at shift change.
- Persons riding on man-riding conveyors should recognize that the practice is only safe if the system is properly designed and maintained, the rules are followed, personal discipline is maintained, and horseplay avoided.
- Training in proper man-riding techniques should be provided, including the use of a simulator to teach prospective users how to board and alight safely from the conveyor. (**Figure 22.5.**)

CLOSING THOUGHTS
A Ticket to Man-Ride

If safety were the only consideration, no worker should ever use a conveyor belt to get to or from a workstation. While it is a common rule for conveyor safety to never sit, stand, step across, or ride on a moving conveyor belt, it must be recognized that for some locations around the world, riding on a conveyor belt is an accepted practice.

It is incumbent on those operations that rely on man-riding conveyors that their systems are engineered, maintained, and operated to the highest safety standards. In addition, they must train their workforce to maintain the proper respect for the conveyor system and in the proper techniques for boarding, riding, and alighting.

It is critical to emphasize that in operations where the conveyors are not designed and equipped for man-riding that unauthorized riding is prohibited. The workforce should be trained in why this is a hazard and in the consequences for violations of this prohibition.

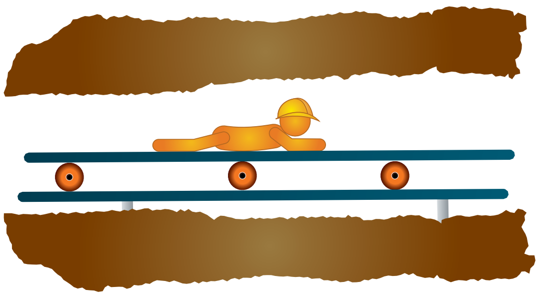


Figure 22.4.

Some man-riding conveyors are designed so workers ride in a prone position.

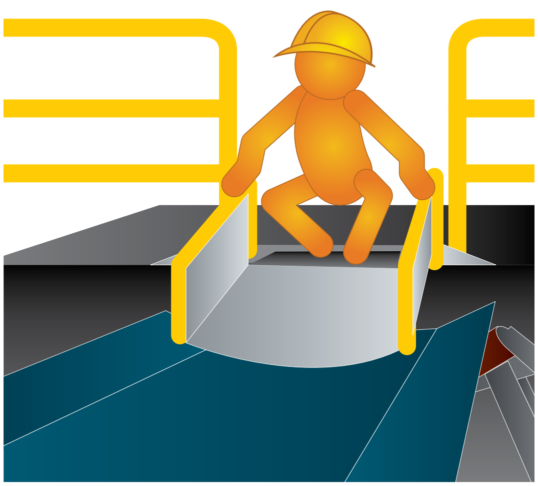


Figure 22.5.

Training in man-riding should include the techniques for properly boarding and alighting from the belt.

3

Chapter 23 Working Safely Around Conveyors

INTRODUCTION

There are a vast number of lists and articles published on safe work practices. The following is an attempt to summarize the current thinking and practices for working safely around conveyors. This information has been gathered from a variety of articles, safety presentations, websites, owner's manuals, and other documents, distilled and combined as appropriate for bulk-materials-handling belt conveyors. Simpler is usually safer, although in an effort to be complete, the authors acknowledge this chapter is anything but succinct.

The following presents a basic guide to practices that can be used by supervisors and workers to operate, clean, and maintain conveyors safely and help assure a safer working environment around bulk-materials-handling belt conveyors.

Although every plant and every jurisdiction has their own set of specific rules for working on and around bulk belt conveyors, the following are some of the most general and most common work practices. Of course, no simple list can cover all hazards and potentials. These represent guidelines and are not specific to any particular situation. (**Figure 23.1.**)

Managing for Safety

Safety management starts with the corporate culture. If the top management espouses safety but focuses on production, the message is clear: this company emphasizes production at the expense of safety.

Today, there is no question that a well-established and -supported safety culture results in a cleaner, safer, and more productive operation. This is reflected in more profitable results, better community relations, and a superior work environment.

Figure 23.1.

Many plants have detailed safety rules; however, no document can cover all situations and circumstances.

The General List for Conveyor Safety

A thorough, systematic review to identify hazards of all tasks and equipment is the foundation of a well-designed conveyor safety program. The following lists are suggested practices management should specify, and workers should follow, to improve safety around belt conveyors.

1. **Help Each Other Work Safely**
   - Report all near misses, unsafe acts and injuries.
   - ANY worker can stop ANY work on ANY machine ANY time.
   - Report to work awake, unimpaired, and mentally ready.
2. **Be Authorized**
   - All workers must be authorized and trained to do the job.
   - Use the 'Buddy System'; No one is authorized to work alone.
3. **Appropriate Attire & Personal Protective Equipment (PPE)**
   - ALWAYS wear safety boots, hard hat, eye and ear protection.
   - Use site- and job-specific PPE.
   - No jewelry, loose clothing, or long hair.
4. **LOTO / BOTO**
   - ALWAYS Lockout / Tagout / Blockout / Testout.
5. **SLAM**
   - STOP: Think through the task.
   - LOOK: Identify the hazards.
   - ANALYZE: Proper tools, parts, and skills.
   - MANAGE: Take the necessary action to see the work is done safely.
6. **Respect the Conveyor**
   - Do not break the plane of a moving conveyor with body or tools.
   - Assume the conveyor can start at any time.
7. **Train for the Job**
   - Know the job.
   - Read and understand the instructions.
8. **Use the Right Tools**
   - Do not use broken or damaged tools.
   - Use the right tools for the job.
   - Do not overload conveyors or equipment.
9. **Security**
   - Keep guards in place.
   - Keep restricted areas locked and blockades in place.
   - See something, say something.
   - Be aware of overhead and traffic hazards.
10. **Clean and Organized**
    - Only clean when safe to clean.
    - Remove discarded materials, tools, and trash.
    - A place for everything and everything in its place.

Safety Around Conveyors: Whose Responsibility

Management	Operator	Maintainer	Cleaner	Visitor	Safety Requirement
X					Establish safe conveyor start-up procedures.
X					Instruct workers on how and when to use E-stop devices such as 'cable pull' wires.
X					Allow only properly trained workers who are aware of the hazards to operate, inspect, repair, or clean the conveyor.
X					Prohibit covering, modifying, bypassing, disabling, or misusing conveyor controls and safeguards.
X					Require all safety guards, covers, and controls to be in place when the conveyor is in operation.
X					Train all personnel in safe work procedures.
X					Restrict conveyor access to only those whose jobs require access.
X					Establish policies and procedures (JSAs) for conducting specific tasks on or around belt conveyors.
X					Assure that safe access is provided to all working areas.
X					Train workers and visitors in the proper use and care of their PPE.
X					Provide hazard-identification training to persons who observe, operate, and work in the vicinity of equipment.
X					Prohibit standing, walking, or riding on the moving conveyor.
X					Investigate all conveyor and personnel accidents or near misses to find root causes.
X					Address changes to equipment, materials, or work processes for new risks.
X					Provide safe access to any area where cleaning or maintenance will take place.
X					Test monthly and document that all safety controls and E-stops are properly working.
X					Label all controls.
X	X	X	X	X	Mitigate identified hazards immediately.
X	X				Do not overload conveying equipment.
X		X	X		Ensure the proper tools are provided, maintained, and used to complete all tasks.
	X	X	X		Ensure manufacturer's manuals are reviewed prior to beginning work.
X	X	X	X	X	Report unsafe conditions.
	X	X	X	X	Be aware that ladders, stairs, catwalks, walkways, and surfaces may be slippery.
	X	X	X		Ensure that all persons are clear before operating the conveyor.
	X	X	X	X	Bind hair and loose clothing before going near conveyors.
	X	X	X		Clean conveyor components only when safe.
	X	X	X	X	Cross conveyor only at designated crossing points.
	X	X	X		Remove 'danger' or 'repair' tags only after the hazard is eliminated or repair completed.
	X	X	X		Keep conveyor walkways, passages, and immediate areas clear.
	X	X	X	X	Maintain communications with all persons working along the conveyor(s).
	X	X	X		Clear all personnel, tools, and materials from the conveyor before starting the belt.
X	X	X	X		Prohibit relying on an emergency stop to (routinely) stop or restart the conveyor.
	X	X	X		Shut down conveyor [LOTO/BOTO] to free, adjust, or repair idlers.
	X	X	X		Shut down and lockout machines before cleaning, oiling, adjusting, or repairing.
	X	X	X	X	Use Lockout / Tagout / Blockout / Testout Procedure.
	X	X	X		Keep people and tools away from moving parts.
	X	X	X		Control falling materials and flying debris.
	X	X	X		Return tools to proper places before the conveyor is restarted.

3

The root causes of many accidents show that management policies, procedures, and controls were inadequate and failed to ensure that persons were protected from hazards that could have been identified, eliminated, or controlled.

Even in an operation with an established and effective safety culture, conveyor hazards are not always sufficiently guarded to prevent inadvertent contact with moving parts. Guards may be left off in a moment of haste or omission, and personnel working around conveyors are not always sufficiently aware of the hazards with conveyor systems. It is management's responsibility to provide and maintain safe equipment and to continuously reinforce safe work practices.

Work Practices for Improved Safety

Each worker should be properly trained in the risks of a bulk-materials-handling environment, the hazards of working on or around belt conveyors, and the risks and techniques of the specific job to be performed. (**Figure 23.2.**)

The plant should establish—and train personnel to follow—policies and procedures for conducting specific tasks on or around belt conveyors. Only authorized, trained, and competent personnel should operate or maintain conveyors and other materials-handling equipment.

Before beginning any work, ensure that workers assigned the job are task-trained and understand the hazards associated with the task. Unless one's job requires it, stay away from the conveyors.

This basic safety training should be repeated frequently, especially as plant equipment is updated.

Persons working on or about a conveyor should know the location and operation of pull-rope stop switches and other control systems. All personnel working near conveyors should be instructed in how and when to use devices such as pull-wire emergency switches to stop the conveyor.

Conducting a workplace examination every shift can prevent injury or death when safety and health hazards are found and fixed. When workplace examinations are performed, workers are protected, problems are identified, and hazards are eliminated.

During every shift, examine each workplace for unsafe conditions; if there is a problem, report it immediately to the supervisor or manager.

All worn or defective tools or equipment are to be reported directly to the area supervisor. Do not attempt to repair any machinery, electrical equipment, or wiring that requires a qualified and/or authorized person.

Workers should report immediately to the supervisor any condition or practice which may pose a risk to people, equipment, property, materials, or the facility.

Personal Protective Equipment (PPE)

The worker must wear, use, and maintain Personal Protective Equipment (PPE) in compliance with the facility regulations and as supplemented for the specific task assignment. Loose-fitting clothing, jewelry, unrestrained long hair, and neckties are prohibited in the production, storage, and movement of bulk materials. In some localities, appropriate clothing is dictated by the plant conditions or the production process. (**Figure 23.3.**)

The following PPE are almost universally required:

Figure 23.2.

Those who work around conveyors should be properly trained in the hazards of conveyors and the risks of the job to be performed.

3

- ✔ Eye protection with permanent side shields
- ✔ Protective helmets (hard hats)
- ✔ Steel-toed work boots
- ✔ Hearing protection
- ✔ A means of two-way communication

Other forms of frequently required PPE include:

- ✔ Gloves
- ✔ Respirators
- ✔ Coveralls and/or vests with reflective stripes and/or fire-resistant fabrics
- ✔ Fall-arrest harness
- ✔ Headlamps or lighted vests

Operating Safely

Each worker should be properly trained in the risks of an industrial (bulk-materials-handling) environment, the risks of working on or around belt conveyors, and in the techniques of the specific job to be performed.

Figure 23.3.

Workers must wear personal protective equipment (PPE) in keeping with the rules of the facility and the requirements of the job to be performed.

Figure 23.4.

To assure worker safety, guards removed to perform maintenance should be returned to position when the service procedure is finished.

It cannot be stressed enough how important it is to keep all body parts clear of conveying equipment while it is in operation. This is one of the most common ways to be injured around a conveyor. As James Normanton and Kris Porter expressed in a 2006 article, "Basic Conveyor Safety," in the National Industrial Belting Association's *Belt Line* newsletter, "Don't put your hands where you wouldn't put your face!"

It is imperative that workers never climb, sit, stand, walk, ride, or even touch the moving conveyor belt at any time. Any such contact exposes workers to the risk of injury from rolling components, moving materials, and obstructions.

Operating a conveyor without the guards is one of the most unsafe, and sadly most common, occurrences in the bulk-materials-handling industries. Guards are sometimes removed by employees to allow maintenance. This exposes moving parts that can be extremely dangerous if left accessible. (**Figure 23.4.**)

Conveyor controls can be very important in the safe running of a conveyor. All the controls and pull cords need to be plainly visible and easily accessible, so that anyone working in the area can reach them. Conveyors should be regularly checked to be sure controls are functioning correctly, and that no one has modified, abused, or disconnected the controls. Training should be given to all employees about where the controls are located, and when to use them.

Conveyors should not be operated beyond identified (design) capacity and limits. Exceeding the capacity, speed, or other specification of the conveyor leads to material spillage and premature component failure; both lead to increased maintenance and thus increase the exposure of workers to hazards.

Cleaning Safely

Protect workers by helping keep the plant clean and tidy at all times. It is important that the area around conveyors be kept clean of fugitive material, and as free of dirt, oil, and other stray material as possible to ensure the equipment continues to operate efficiently. But it can be hazardous to perform cleaning and maintenance when the conveyor is powered and operating. Cleaning around the conveyor while the conveyor is in operation must be done very carefully, and only if all safeguards are in place. Make sure the area around the conveyor is free from tools and objects that may cause trips or slips. Keep the area around conveyors free from obstructions such as tools, airlines and hoses, discarded or new parts, or packing materials. This is especially true for areas around the loading and unloading points of the conveyor, where workers will pass or pause to observe operations.

Measures to prevent the escape of fugitive material from the conveyor offer improvements through reduced maintenance and cleaning labor, which in turn reduces both plant expenses and worker exposure to hazards. (**See Chapter 24 Conveyors, Fugitive Material, and Cleanup.**)

Maintaining Safely

Today, safety-minded companies realize maintenance is a core safety activity that must be professionally managed, measured, and performed proactively as much as possible.

Always follow the proper procedures, including LOTO / BOTO. There are technicians who sometimes become too confident in their ability to work on machinery even when it is connected to power because they have been around the system a long time and know it well. It is important that workers—no matter how experienced—do the appropriate preliminary procedures prior to starting any work on a conveyor or other system.

Verify all conveyors have the proper safety equipment, and that it is all installed properly and operational.

Do not work on or around a moving conveyor, or one that can move. (**See Service Exception and Safe to Service sections.**)

Never remove guards to work on operating conveyors.

Job Safety Assessments (JSAs) should be performed for each maintenance task and updated as equipment changes, or at a minimum every two years. Only authorized (trained and competent) personnel should operate or maintain conveyors and other materials-handling equipment.

When in doubt, ask. Consult with local managers and safety officials before starting/restarting operations.

Visiting Safely

Plants and mines receive visitors on a regular basis. Some visitors are familiar with the industrial environment and others are infrequent visitors who may not be aware of common conveyor hazards. Often, visitors must be guided by an experienced plant employee. Safety regulations in many countries require site-specific training for visitors who are on site for a limited number of days per year.

Visitors to a plant should be briefed on safety requirements, be inspected for potential issues with clothes or hair, and given appropriate PPE before being allowed near the conveyor system.

Lockout / Tagout / Blockout / Testout (LOTO / BOTO)

Statistics show that a significant number of injuries and fatalities occur during inspection, adjustment, and maintenance of conveyors. The most serious injuries and the most common hazards involve entrapment or entanglement in moving machine parts. Many of these could have been prevented if the conveyor systems were properly isolated from energy sources prior to any maintenance work being performed. (**Figure 23.5.**)

This isolation from the energy source is done by what is commonly called a lockout / tagout procedure. The use of lockout / tagout is the attempt to assure safety for operations and maintenance workers who must work on or around machinery including conveyors. A typical lockout / tagout procedure—sometimes shortened to LOTO or LO/TO—includes the following rules.

1. Each worker is required to place a personal lock on the de-energizing switch or switches. This may require one lock or multiple locks.
2. Only the employee who places each lock has the key to that lock, and only that employee can remove the lock.
3. If a number of employees are working in a given area, each should place a lock on the power source. Some equipment will have numerous locations that may require lockout.
4. Each employee who places a lock should also place a tag with the employee's name, photo, and contact information.
5. Only the person who locked out the system can unlock it. This prevents someone from starting the conveyor belt unknowingly while someone else is working on it.

Company management is responsible for training employees on the lockout / tagout procedures used within their workplace. While a company may have purchased padlocks and lockout devices for a wide range of applications, it is critical to ensure that employees are appropriately trained to perform the actual lockout procedures. Authorized workers must know how to properly isolate equipment to ensure that hazardous energy is reduced to a 'zero state' and stays that way until servicing is complete. Otherwise, the risk of injury or death is imminent.

Figure 23.5.

Lockout / Tagout of the power supply is a key part of any industrial maintenance procedure, and particularly for belt conveyor service.

In the interest of improving conveyor safety, the authors advocate an expanded isolation called Lockout / Tagout / Blockout / Testout procedure, often abbreviated as LOTO/BOTO. (**See What We Mean By LOTO/BOTO: Terms and Procedures.**) (**See also Chapter 25 Blocking the Belt.**)

Where properly applied, the Best Practices for Lockout / Tagout / Blockout / Testout are a core strategy for working safely around and on belt conveyors and related machines.

Release from Lockout

When the maintenance or repair work is completed, powering up the equipment that had been locked out also calls for a procedure of several steps to ensure worker safety and to prevent equipment damage. It is important to note that performing the first four steps in this following suggested process should be done before any Lockout / Tagout (LOTO) devices are removed.

- Check machines and equipment, removing tools and nonessential items from the conveyor and the immediate work area.
- Replace machine guards.
- Check for employees to make sure the work area is clear and that all workers are safely away from the equipment.
- Notify control room and all affected employees that the LOTO devices will be removed.
- Remove blocking devices.
- Employee(s) who applied the lock(s) in the first place remove their own LOTO devices.
- Confirm with control room and all affected employees that the LOTO devices have been removed.
- Sound the start-up alarm.
- Test run the conveyor.
- Restore power to the conveyor.

The assistance of additional authorized employees may be needed to energize certain sections or parts of the system, if it is not part of a unified sequence from a single control.

Restart Checklist

In its 2016 guideline, *Safety Around Belt Conveyors*, the Conveyor Manufacturers Association of South Africa, Limited provides the following safety check for use prior to restarting a conveyor:

> 4.6 *Basic Check List Prior to Re-starting a Conveyor*
>
> Ensure that:
>
> ✔ nobody is working on the belt;
>
> ✔ guards have been re-fitted and that all the safety interlocks are operational;
>
> ✔ the area is clean and clear of equipment and/or debris or spillages;
>
> ✔ all the firefighting and fire-suppression devices and equipment are in place and operational;
>
> ✔ all clamps are removed or released;
>
> ✔ all other spragging [anti-rollback] devices have been removed;
>
> ✔ the takeup system is operational.

Safety from the Start

Safety requires that no conveyor is started unless the person pushing the start button is certain that all persons are clear. Therefore, the standards specify a positive audible or visible warning system is needed to accommodate different industrial conditions. (**Figure 23.6.**) (**See Chapter 5 Start-Up Alarms.**)

The consequences can be grave if a conveyor is powered up and begins to move when workers are in the vicinity, working near or on the conveyor. Accordingly, conveyor operators must follow specific procedures to ensure the conveyor is clear of all foreign objects and people before starting. But there are still the risks that a less-than-observant operator will not see workers on or near the conveyor who

What We Mean By LOTO / BOTO: Terms and Procedures

To be certain of an understanding of the steps in the Lockout / Tagout / Blockout / Testout process, the following will define the steps in the process.

Lockout Procedure for each worker to place a lock(s) on the primary energy source(s) to ensure that machines remain de-energized and inoperable while cleaning, repairs, or adjustments are made.

Tagout Placement of a 'Warning/Danger: Do Not Operate' tag on the locking mechanism attached to the disabled equipment. Tags and signs are not used alone; tags or signs are used in addition to locks. Tags must state the reason for the lockout, the name of the employee who is working on the equipment, how that person may be reached, and the time the tag was put in place.

Blockout Restrains a part or mechanical system to prevent movement or release of stored energy in any direction, which would pose a danger to personnel. Restraints may be by pinning, bolting, depressurizing, clamping, or any method which will not allow unintentional, mechanical, or bulk-material movement.

Testout Provides a final check on whether a conveyor (or other system) is truly OFF by attempting to restart the system (by pushing the START button, for example). An operation should try to start the belt conveyor or interlocked equipment after the lockout lock has been placed but before the maintenance work begins. Another way to say this is 'Tryout' (as in 'Try out the equipment' or 'Try out the controls'). This procedure should include both local start/stop stations and the system's remote controls to ensure that the correct controls were de-energized.

Using this four-step Lockout / Tagout / Blockout / Testout process means completing the pre-work safety procedure may take a little longer, and so potentially delay the start of actual maintenance work. However, it decreases the potential for injury to workers.

are put in peril by a too-soon movement of that conveyor.

After three workers died in a relatively short period when the belt conveyors each was working on (individually) started unexpectedly, Mine Safety and Health Administration. (MSHA) in the United States issued a hazard alert to address conveyor start-up risks. To improve safety for conveyor workers, the *MSHA Hazard Alert: Conveyor Startup Fatalities*, advised the following:

- De-energize, lock, and tag the drive motor
- Establish and follow safe work procedures
- Train miners on general safety and tasks assigned
- Maintain communication with all miners
- Visually check conveyors before startup
- Account for all miners on a work team
- Provide [and use] a pre-startup alarm ...
- Sound the alarm before conveyor startup
- Use fall protection when a fall hazard exists
- Provide and maintain a safe means of access to all working places

3

Figure 23.6.

Consequences can be grave if a belt begins to move while personnel are working on or near the conveyor.

Figure 23.7.

Many regulations allow some procedures to be performed while the belt is in motion.

While prestart warnings (audible and/or visual signals) are required, it is important that they actually be actuated and that they are heeded by workers. When the alarm sounds, workers must get away from the conveyor, and/or pull the stop-rope switch.

The Minor Service Exception

Many managers believe that working on a moving conveyor under any circumstances is against the law. However, most regulations allow some adjustment and maintenance activities to be performed while the belt is running. From a practical standpoint, there are procedures that need to be done with the conveyor running, such as training the belt so it tracks in the center. In addition, there are many activities related to keeping the belt running clean, such as belt cleaner maintenance, which can be performed safely—within specified limits—while the belt is running. (**Figure 23.7.**)

This is referred to as a minor service exception or maintenance exception. These exceptions apply only to minor servicing activities that must be performed during normal production operations—for example, the utilization of a machine for its intended production function—and that are necessary to allow production to proceed without interruption. This exception applies only if the employer provides effective alternative protection from hazardous energy.

To be considered 'minor servicing,' as defined by the Occupational Safety and Health Administration (OSHA) in the United States in a 'Hot Topics' post on its website titled *Relationship of 1910.147, The Control of Hazardous Energy (Lockout/Tagout) Standard, to Subpart O, Machinery and Machine Guarding Standards*, the activity must be:

- **Routine:** Performed as part of a regular, basic course of procedure.
- **Repetitive:** Repeated regularly as part of the production process or cycle.

- **Integral:** Inherent to, and be performed as part of the production process.

It is important to note the minor service exception is acceptable only as long as the operation performed replaces Lockout / Tagout with "alternative measures of effective protection." OSHA then specifies:

> Some acceptable alternative measures include specially designed tools, remote devices, interlocked barrier guards, local disconnects, or control switches which are under the exclusive control of the employee performing the minor servicing. These alternative measures must enable the employee to safely perform the servicing task without being exposed to the unexpected energization or activation of the equipment, or the release of stored energy.

To paraphrase, maintenance can be conducted on energized equipment (for example, conveyors) if, and only if, the procedure has been designed and proven to be at least as safe when the conveyor is not operating. Documenting the service procedure and the training in the alternative method of protection increases the effectiveness of the procedure and the protective measures.

An effective way to develop these safe procedures for minor service activities is to perform a Risk Analysis and to develop Job Safety Analyses for the specific maintenance activities under consideration.

The decision on whether or not to allow such minor servicing while the conveyor is in operation lies with each company's management, in addition to the regulations as written by local, state, or province.

REGULATIONS AND STANDARDS

Australia

Minor Service Exception

In section 5.1 *Maintenance Involving Stored Energy*, the Australian standard *AS NZS 4024.3611:2015 Conveyors – Belt Conveyors for bulk materials handling* forbids maintenance be performed unless all drive and stored energy have been released and/or isolated. In circum-

Safety Idea Publication Endorses Lock, Tag, and Block

In 2010, the Mine Safety and Health Administration (MSHA) in the United States published the following as its *Accident Prevention Program Safety Idea AP2010-98976:*

> Before Working on or Traveling under a Conveyor Belt Stop, De-energize, Lock and Tag, & Block from Motion

From 2000 thru 2010, nearly 30 miners have been killed around surface and underground conveyor belts. Over half of these fatalities may have been prevented had miners and mine operators used and practiced the following procedures when working around conveyor belts.

- **STOP**

  Do not work or travel under a conveyor when it is operating, and do not attempt to place your arm or a tool near a roller or other moving part when the belt is on or may start. Remember to STOP and think about the following life-saving procedures.

- **De-energize**

  Stop the belt by switching off the power and disconnecting the electrical circuit at the breaker panel or motor control center.

- **Lock and Tag**

  Once the power is disconnected, lock and tag to assure the conveyor belt cannot be energized while you're working around it.

- **Block from Motion**

  Accidents have occurred when stored energy moved a stopped conveyor belt and entangled unsuspecting miners. Securing the belt from unintended motion can help assure your safety.

stances where it is not reasonable to isolate or discharge the stored energies, the risks must be eliminated by controlling the energy.

Any maintenance activities that must be performed when any stored energy—such as gravity or belt tension—is still present in the system, shall be performed only after a procedure has been devised and put in place that allows the work to be performed safely. The standard cites maintenance activities, such as the installation or removal of a belt, the replacement of idlers, or adjustments to control a belt's path only be performed when a safe work procedure will allow service work while the conveyor has stored energy.

In keeping with the development of this 'safe work procedure,' some Australian mines have allowed the use of belt-cleaning equipment and service procedures that allow cleaner service while the belt is running; (**See How Australia's ESS Performs Cleaner Service with the Conveyor Running.**)

Brazil
Minor Service Exception

In Brazil, standard *NR-22 – Safety and Occupational Health in Mining* notes in 22.8.10:

> Any cleaning or maintenance work on belt conveyors shall only be performed with the equipment stopped and locked, except when cleaning with water jet or other method, in which case suitable protection devices against accidental contact with moving parts by the worker must be installed.

The standard *NR-12 – Safety in Machinery and Equipment Work* specifies in *NR-12.113*:

> The maintenance, inspection, repairs, cleaning, adjustments and other interventions that are necessary shall be performed by trained, qualified or legal skilled professions, formally authorized by the employer, with machinery and equipment stopped and adoption of the following procedures: ...
>
> (b) electrical and mechanical lock in "off" or "closed" position of all cut devices of energy sources, in order to prevent re-energizing, and signaling with lock card or tag containing the time and date of locking, the reason for the maintenance and the name of the person responsible.

Canada
Lockout / Tagout

For Canada, the Commission de la Santé et de la Sécurité du Traval du Quebec/Institut de recherche Robert-Sauvé en santé et en sécurité du travail (CSST/IRSST) guideline, *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones,* notes in section 5. Safeguards against Maintenance Hazards (5.1 General Principles) notes:

> Equipment must be designed in such a way that maintenance (adjustments, greasing, cleaning, unjamming, unclogging, etc.) can be accomplished away from danger zones. Therefore, all adjustment and grease points must be accessible without having to remove guards or other protective devices.
>
> When it is necessary to open or remove guards, or even to neutralize protective devices in order to carry out a maintenance procedure, safeguards must be implemented to ensure worker safety in the areas transformed into danger zones. These measures must conform to sections 185 and 186 of the *Regulations Respecting Occupational Health and Safety* [of Quebec].
>
> According to section 185 of the *Regulation Respecting Occupational Health and Safety*:
>
> > Subject to the provisions of section 186, before undertaking any maintenance, repair or unjamming work in a machine's danger zone, the following safety precautions shall be taken:
> >
> > (1) turn the machine's power supply switch to the off position;

(2) bring the machine to a complete stop;

(3) each person exposed to danger locks off all the machine's sources of energy in order to avoid any accidental start-up of the machine for the duration of the work.

For additional information, the CSST/IRSST *Users Guide* refers to the American National Standards Institute (ANSI) standard *Z224.1-2003 Control of Hazardous Energy Lockout/Tagout & Alternative Methods* and Canadian Standards Association (CSA) standard *Z 460-13 Control of Hazardous Energy – Lockout and other Methods*.

For Alberta, the *Best Practices on Conveyor Safety* guide specifies in section 5.2 that "Lockout/isolation procedures should be an integral part of overall maintenance and operating procedures." The section additionally notes, "Legislative requirements for isolation of hazardous energy under the Alberta Occupational Health and Safety Code must be followed."

Minor Service Exception

In Ontario, the *Occupational Health and Safety Act (R.R.O 1990 Reg. 854), Mines and Mining Plants* notes in section 196 (6):

> A conveyor shall be stopped and the prime mover de-energized, locked and tagged out when the conveyor is undergoing repairs, adjustments or maintenance unless,
>
> (a) it is necessary to run the conveyor during such work; and
>
> (b) special precautions are taken to prevent injury to a worker from moving parts.

WorkSafe Alberta's *Best Practices on Conveyor Safety* notes in Table 2.4 (**Figure 23.8**) that lockout procedures apply for the cleaning of conveyor parts. Housekeeping under the conveyor is authorized if the danger zone is protected by a guard; lockout is required when the danger zone is not guarded.

Europe
Lockout / Tagout and Minor Service Exception

Safeguards for Maintenance Activities *Hazard Assessment Must Be Done for Each Activity*	
Adjustment and fit	Authorized at all times, provided adjustment points (for example, scraper, drum and take-up system adjustment) are outside the danger zone. Lockout if adjustment points are inside the danger zone. Application of stipulations in the above section 5.3 of this guide.
Greasing and oiling (lubrication)	Authorized at all times where grease points are outside the danger zone. Lockout if grease points are inside the danger zone.
Conveyor parts cleaning or maintenance (drums, rollers, chassis, etc.)	Lockout procedures apply. Operation [is] authorized if housekeeping can be done: • with an automated (air or water) jet; or • according to the above section 5.3 of this guide.*
Housekeeping under and around conveyor; disposal of material recovered on the belt	Authorized at all times as long as the danger zone remains protected by a guard … Lockout if the danger zone is not protected with a guard. Apply measures in the above section 5.3 of this guide, should the conveyor need to be operational. *[Section 5.3 requires that only those workers competent in correcting a hazardous condition, and the miniuumn number necessary, should be exposed to a hazard. It further requires every reasonsable effort be made to control the hazard while the condition is being corrected – Ed.]*

Figure 23.8.

Extracts from WorkSafe Alberta's Best Practices on Conveyor Safety Table 2-4 *"Safeguards for Maintenance Activities."*

German Institute for Normalization (DIN) EN 620 Continuous handling equipment and systems – Safety and EMC requirements for fixed belt conveyors for bulk materials provides an exception for servicing which seems to be somewhat more restrictive than the regulation in other jurisdictions such as the United States, but still allows for maintenance and inspection activities during conveyor operation. Section 5.8 Measures for protection against hazards arising during inspection, maintenance and cleaning states:

> The equipment shall be designed so that, as far as possible, adjustment, lubrication, inspection, cleaning and maintenance may be performed outside danger areas in accordance with 5.1.4.1. [Section 5.1.4.1 requires that "All lubrication and adjustment points used more frequently than monthly shall be accessible without it being necessary to remove any guards."]
>
> Where it is necessary to remove safeguards, for the performance of maintenance, repair, inspection, or cleaning work, then measures shall be provided for the protection of the personnel, in the resulting danger areas. These measures shall be effective on units being repaired or maintained and also on other parts of the system, which may be in operation.
>
> Such measures shall be one, or a combination of the following, or measures giving equivalent levels of safety:
>
> — isolation and/or energy dissipation devices(s) for part(s)or for the complete system;
>
> — hold to run devices;
>
> — speed reduction devices;
>
> — limited movement control devices;
>
> — creation of maintenance or repair islands by protective means, e.g. providing temporary fencing or barriers. (See also 5.1.6, slip, trip and fall hazards.)
>
> — If, for technical reasons, maintenance work cannot be carried out with the conveyor at a standstill, then safety measures shall be taken. These may include the installation of:
>
> — systems for reducing the speed;
>
> — systems for controlling the amplitude and number of movements;
>
> — anti-run-back devices.

South Africa
Lockout / Tagout

In Chapter 8 of *Conveyor Regulations of the Mine Health & Safety Act* (Act No. 29 of 1996) (as amended in 2013) specifies the following:

> 8.9(1)
> … The employer must ensure that …
>
> (b) the power supply and all sources of stored energy of a stationary conveyer belt installation are isolated, made safe and locked-out during either repairs, maintenance or cleaning of spillage in the designated sections; provided that the alignment and training of a conveyor belt installation may be carried out whilst the belt is in motion subject to it being carried out in accordance with a procedure prepared and implemented for this purpose.

Minor Service Exception

According to the 2016 guideline from the Conveyor Manufacturers Association of South Africa, *Safety Around Belt Conveyors*, in section 4.5 Safe Operating Procedures: "The only action that can be undertaken with the belt in motion is tracking of the belt."

In its section 4.3 Lock out Systems, the CMA guideline notes:

> When any work is carried out on the conveyor, whether to the belting, components, or to the structure, the responsible person must ensure that the system

> is properly locked out, following the prescribed lock out procedures.
>
> Where more than one team is required to work on the system concurrently, multiple lock out procedures must be applied in accordance with the regulations and the applicable risk assessment.

The CMA publication further explains in section 4.1 Safety Requirements for Maintenance:

> The prohibition of work on moving machinery relates to tasks such as belt cleaning, house-keeping and the removal of spillage at localised points. Where build-up of carry-back material occurs on the face of pulleys and idler shells, the removal of this build-up is only permitted when the conveyor system has stopped and been safely locked out.
>
> In instances where work needs to be carried out on the conveyor while the belt is running, such as belt training or the adjustment of material stream deflectors, it is important that this be performed by competent teams, in accordance with approved risk assessments and safe working procedures pertaining to the task being performed. While undertaking the necessary task, it's important for operators to be on the alert and to stop the conveyor by activating a pull key or an emergency stop button which must be readily accessible. In all cases, except for those mentioned in the previous paragraph, pull keys and 3-phase isolation must be locked out and tagged prior to the commencement of any maintenance, construction or repairs.

As noted in the Venetia Mine's *Mandatory Code of Practice for the Safe Use of Conveyor Belt Installations for the Transportation of Minerals, Material 0r Personnel – Revision 2* (*Venetia Mine COP*), De Beers Consolidated Mines uses a job assignment or title of "Plant Monitor." This is defined as "a person appointed to ensure smooth and safe running of the Ore Processing Plant." Overall duties of a plant monitor include the inspection and monitoring of equipment and system parameters, and the ensuring of general housekeeping in the plant.

As spelled out in the *Venetia Mine COP's* section 8.3.25.5, conveyor-related duties of a plant monitor are:

- To check for and clean up spillage of material.
- To check correct loading of the belt. When abnormally large rocks are continually noticed on the belt, report to the shift foreman. Should a dangerous situation arise the belt must be stopped immediately.
- To check for any obstructions between guards and pulleys.

The *Venetia Mine COP* contains a number of restrictions on conveyor work in section 8.5.1 Conveyor Belt Installation Safety Rules:

- Only trained, competent persons will be allowed to operate any conveyor belt installation. The plant monitor must know and understand the safety rules critical to the safe and smooth operation of any conveyor belt installation.
- Whenever belt conveyors are to be stopped on a planned basis, the plant monitor shall ensure that loaded conveyors are emptied before stopping the system, unless dictated otherwise by the normal operating procedure or requested by the maintenance personnel.
- Visual conveyor inspections must be conducted subsequent to any equipment being stopped for maintenance and/or shutdowns prior to the conveyor being started.
- An examination by the plant monitor, specifically drive units, guarding, spillage and belt training shall be carried out as soon as reasonably practical after start-up of the belt conveyors.
- While the belt conveyor is running, the plant monitor will patrol the entire length of the system to check for any serious defects.

- If any serious defect is found, the plant monitor shall stop the belt and report the unsafe or unsatisfactory condition.
- No maintenance, repairs or removal of guards may be allowed while the conveyor is in motion. No conveyor shall be operated without adequate guarding.
- Where guarding has been removed for the purpose of cleaning, maintenance or repair, the conveyor shall be de-energised and locked out as per the De-energise, Isolate, Lock-out, Test and Make Safe Policy.
- No cleaning operations of spillage on conveyor deck plates, near any rotating pulley or idler may be carried out where physical contact can be made with any cleaning tool while the conveyor is in operation.
- No sample [of the belt cargo] shall be taken unless that conveyor is completely de-energised and locked out as per De-energise, Isolate, Lock-out, Test and Make Safe Policy.

The *Venetia Mine COP* provides additional guidance on work practices in section 8.3.24 De-Energising and Lock-out System:

> No person shall carry out work on a conveyor belt installation or any other installation (e.g. lighting installations attached to conveyor belt installation) which may expose persons to hazards associated with a conveyor belt installation, unless the drive has been de-energised, isolated, tested, locked out, tagged and verified safe.

This does not apply where the installation is required to run for training of a conveyor belt, adjustment of scrapers, calibrating the belt scale or speed switches, or any other calibration work. Such operations shall be carried out by a competent and authorized person.

United States
Lockout / Tagout

Issued in 2003 and revised in 2014, *ANSI/ASSE Z244.1-2003 Control of Hazardous Energy – Lockout/Tagout & Alternative Methods* establishes requirements for the control of hazardous energy associated with machines, equipment, or processes that could cause injury to personnel. Joseph J. Lazzara in an article on *ehstoday.com*, "New Lockout/Tagout Standard Details Ways to Better Safety," assessed the ANSI/ASSE requirements this way: "The foundation of the LO/TO standard is its use of a systematic procedure designed to identify, analyze and correct safety problems."

In *29 CFR 1926.555(a)*, OSHA in the United States requires:

> Conveyors shall be locked out or otherwise rendered inoperable, and tagged out with a "Do Not Operate" tag during repairs and when operation is hazardous to employees performing maintenance work.

MSHA in the United States has a variety of standards that relate to LO/TO, depending on procedures for each piece of equipment that may be serviced or maintained. (**Figure 23.9.**)

30 CFR 56.12016 Work on electrically-powered equipment notes:

> Electrically powered equipment shall be deenergized before mechanical work is done on such equipment. Power switches shall be locked out [lockout] or other measures taken which shall prevent the equipment from being energized without the knowledge of the individuals working on it. Suitable warning notices [tagout] shall be posted at the power switch and signed by the individuals who are to do the work. Such locks or preventative advices shall be removed only by the persons who installed them or authorized personnel.

A typical requirement is found in *30 CFR 56.14105 Procedures during repairs or maintenance*:

> Repairs or maintenance of machinery or equipment shall be performed only

> after the power is off, and the machinery or equipment is blocked against hazardous motion.

According to the article, "Lockout/Tagout Rules for Safer Mining," by Matt Dudgeon published in *Inside Global Mining,* "Under MSHA standards, training is required under Part 48 or Part 46 to cover basic LOTO principles, as well as specific task training that can include the LOTO procedures."

Minor Service Exception

In the United States, OSHA recognizes that some minor servicing may have to be performed during normal production operations, so a lockout / tagout exception is allowed.

In *29 CFR 1910.147*, OSHA recognized circumstances in which servicing and maintenance activities would be performed (in full or in part) without locking out or tagging out the machinery or equipment. One such circumstance is detailed in section *1910.147*(f)(1), which recognizes that lockout / tagout devices must be temporarily removed in limited situations to permit testing or repositioning, and establishes procedural steps to maintain the integrity of any lockout / tagout program.

The requirements for the minor service exception are detailed in OSHA *3120 Control of Hazardous Energy: Lockout/Tagout*, as revised in 2002:

> Work involving minor tool changes and adjustments or other minor servicing activities that are routine, repetitive, and integral to the use of the production equipment and that occur during normal production operations are not covered by the lockout/tagout standard. This exception is limited, however, and applies only when … the employer provides and requires alternative measures to ensure effective, alternative protection.

MSHA regulations are similar, saying in *30 CFR 56.14105 – Procedures During Repair or Maintenance*:

> Machinery or equipment motion or activitation is permitted to the extent that adjustments for testing cannot be performed without motion or activation, provided persons are effectively protected from hazardous motion.

MSHA's regulations for coal mines are similar, as both MSHA *30 CFR Part 77 (Surface Mines*) section 77.404(c) and *30 CFR Part 75 (Underground Mines)* section 75.725 state:

> Repairs or maintenance shall not be performed on machinery until the power is off and the machinery is blocked against motion, except where machinery motion is necessary to make adjustments.

Subsection (c) of section 5.2 Maintenance (Repair) of *ASME B20.1-2009 Safety Standards for Conveyors and Related Equipment* states, "No maintenance or service shall be performed when a conveyor is in operation except as provided in paras. 5.3 and 5.4." Paragraphs 5.3 Lubrication and 5.4 Adjustment or Maintenance During Operation each note that only "trained and qualified personnel who are aware of the hazard of the conveyor in motion" can perform the service referred to in the specific paragraph's title.

Service-Friendly Components

Systems and components can often be designed to be safe to service by considering human nature. If the easy way to service

MSHA Regulations on Lockout / Tagout	
Metal/Nonmetal (Surface or Underground)	*30 CFR 56/57.12016*
	30 CFR 56/57.12017
	30 CFR 56/57.14105
Underground Coal	*30 CFR 75.509*
	30 CFR 75.511
	30 CFR 75.820
	30 CFR 75.1725
Surface Coal	*30 CFR 77.404*
	30 CFR 77.500
	30 CFR 77.501
	30 CFR 77.704

Figure 23.9.

MSHA Regulations for Lockout / Tagout.

3

a component is also the safest way, human nature would tend to intuitively follow this safe and easy method. If the work as designed is not simple, workers will look for easier ways to do it. If the safe way is not easy, workers will—sooner or later—look for ways that are easier, even if not as safe.

If systems and components are designed to be simple—so they can be operated, assembled, installed, or maintained in only one way—they will be easier, quicker, and safer to service.

Human nature also tells us that more service attention will be provided to components designed for safe, efficient, ergonomically correct maintenance than to those components installed in dirty, poorly lit locations, and which require workers to stoop or lay on the floor to inspect or access.

The concept of designing components so they can be readily, easily, and safely serviced can be summed up by the phrase, 'service-friendly.' This concept is often called 'Safety through Design' or 'Safe Design.'

Companies with a strong safety culture understand the return on investment for specifications and designs that improve safety. This can be called **Return on Conveyor Safety™ (R.O.C.S.™)**. Surveys of industry and safety literature performed in researching this book indicate the average return on investment for safety-related features is on the order of 80 percent.

Figure 23.10.

Some belt-cleaning systems are designed to allow 'safe-to-service' procedures.

From the point of view of the designer and engineer, it is usually time consuming and more difficult to simplify components. It takes more thought to design for intuitive installation, operation, cleaning, and maintenance. The reward for this effort is almost always substantial; the benefit of reduced human suffering is—as the cliché states—priceless.

Safe-To-Service Systems

The demand for commodities and the need for profitable production has led owners and managers of large bulk-handling operations to run for longer periods between routine maintenance outages. The desire to return to operation has led to the abbreviation of these outages, with many and sometimes conflicting projects scheduled. The outages are commonly busy times, with in-house and contractor personnel working on tight schedules to complete an array of projects before the scheduled restart date. (**Figure 23.10.**)

During outages, there are many temporary hazards introduced to a facility by the nature of fast turnaround maintenance. These 'new' hazards include issues such as worker and equipment congestion, hot work, the movement of materials and equipment, and electrical testing.

If the plant is not shut down—so the belts are running—many of these temporary hazards do not exist. This offers the possibility of doing certain routine service activities while the belt is running more safely than when the belt is shut down.

Conveyor components can be designed so they can be safely adjusted or serviced with the belt running. Components that are good candidates for a safe-to-service-while-the-belt-is-running design include belt trackers, belt cleaners, and flow deflectors.

Safe-to-service designs provide another benefit. Components that are critical to the safe and productive operation of a conveyor system are often and unfortunately neglected or dropped from the work list during planned outages. This is because—when time is critical—the conveyor will still run even if service is delayed to the next outage. It may not run as well, but it will likely still operate. The use of safe-to-service components will prevent this situation by allowing the maintenance to be performed without requiring an outage.

An important ingredient in any plan to allow work when a conveyor is operating, is the proper design of components that need to be serviced to provide maximum safety for the workers who are given those tasks. The safety of these workers must be accounted for through using safe-to-service ideas in the engineering of the conveyor and its various components.

How Australia's ESS Performs Cleaner Service with the Conveyor Running

Some mines in Australia are now allowing service technicians to perform service while the conveyor is running.

Using specially designed equipment, service technicians from Martin Engineering's licensee Engineering Services & Supplies Inc. Pty Ltd (ESS) are approved to provide belt-cleaner service while the conveyor is running at select Australian mines.

ESS Product Development Manager Terry Thew explains, "We only service cleaners with the belt running at a couple of sites—and that is only the Martin® DT2 Inline Secondary Cleaner."

As a secondary cleaner, the Inline Secondary Cleaner is mounted so the cleaning blades contact the belt as the belt leaves the head pulley or in other accessible positions on the belt return.

By releasing the blade-to-belt contact tension from outside the chute and removing a pin, the complete blade cartridge can then be pulled along the cleaner mainframe and out an access door. The mainframe and blades assembly slide out from the side of the conveyor, while the worker stays outside the plane of the conveyor away from the danger zone.

Thew explains, "The final say on this service-while-the-belt-is-running procedure is always up to the individual mine and its safety management." He continues:

> It is highly unusual to get permission. Most mines have decreed that NO work will be done around a moving conveyor. But we have the equipment that allows our carefully trained maintenance technicians to safely service these cleaners while the belt is running. That provides productivity advantages for both the mine and the service crew.

Even if service is not allowed while the belt is running, an operation can have a significant advantage, Thew says:

> The technicians can maintain a cleaner quickly, easily, and safely even if it needs to be during a shutdown. Reducing the duration of the job, and removing as many hazards (and paperwork) as possible, is the goal.

Belt Cleaner Maintenance While Conveyor is Running

The premium inline blades slide into a removable blade cartridge which extends past the cleaner mounts located outside the chute This cleaner is suitable for service while the conveyor is running as it allows the blade assembly to be pulled out of the cleaning position by a handle on the end of the mainframe.

These safe-to-service ideas include designs that provide access while allowing the workers to remain outside the plane of the conveyor (the belt edge) and so away from rolling components. There are a variety of components that are available that allow slide-in/slide-out service, including various idlers, belt-support cradles, and belt-cleaning systems. These track-mounted components allow maintenance workers to pull the components out for inspection or adjustment, and then return them to the proper position from a safe distance outside the enclosure or hazardous area.

BEST PRACTICES
Service While the Belt is Running

The use of components designed for safe and easy service will provide benefits for the maintenance of the conveyor components that are often neglected in planned or emergency outages. This maintenance will improve the performance of the components and of the entire system.

By developing and using systems that allow service while the belt is running—in combination with well-written Job Safety Assessments and proper access—critical maintenance and cleaning activities can be completed safely. Service while the belt is running will free maintenance personnel to perform critical tasks on other systems, minimizing operational downtime. It also allows the conveyor components to receive the service required to provide efficient performance without needing an outage.

Best practices for service while the belt is running include:

- Evaluate the operation to determine which activities or components are candidates for service with the belt running (for example, belt tracking, belt cleaning, and flow centering).
- Perform risk analysis with the goal of reducing the direct risks of the task and mitigating the symptoms of delayed maintenance by more efficient component function.
- Obtain local approval—both in-plant and appropriate regulatory agencies—for any service-with-the-belt-running activities.

Conveyor Safety Checklist

This following checklist was published in 2011 in *For Your Safety*, a weekly health and safety email to members from the Institute of Scrap Recycling Industries, Inc. (ISRI).

- ❑ Are guards installed for all sprockets, chains, rollers, belts, and other moving parts?
- ❑ Are prominent warning signs or lights installed to alert workers to the conveyor operation when it is not feasible to install guarding devices?
- ❑ Do all conveyor openings such as wall and floor openings, and chutes and hoppers, have guards when the conveyor is not in use?
- ❑ Are start buttons guarded to prevent accidental operation?
- ❑ Do conveyor controls or power sources accept a lockout/tagout device to allow safe maintenance practices?
- ❑ Are audible start-up alarms provided for the conveyor?
- ❑ Do all accesses and aisles that cross over or under or are adjacent to the conveyor have adequate clearance and hand rails or other guards?
- ❑ Are crossovers placed in areas where employees are most likely to use them?
- ❑ Do all underpasses have protected ceilings?
- ❑ Are appropriate hazard warning signs posted at all crossovers, aisles, and passageways?
- ❑ Is emergency egress considered when determining placement of crossovers, aisles, and passageways?
- ❑ Are conveyors equipped with interlocking devices that shut them down during an electrical or mechanical overload such as product jam or other stoppage?

Management Commitment to Working Safely Around Conveyors

Requirements for management include:

- **Culture of Safety**
  A management team dedicated to safety will produce significant levels of performance compared to those in the industry who give only lip service to safety. Above all, employees should feel obligated to report all incidents and unsafe acts.
- **Clear and Simple Rules for General Safety**
  If workers cannot recite the facility's main safety rules from memory, then there are too many fundamental rules. Reduce the overall safety strategy into a short list against which all actions can be judged.
- **Training**
  Training to develop safe habits and practices is fundamental. Training needs to be frequent and key topics should be reviewed annually.
- **Preventative Maintenance**
  As noted by Rene Galleguillos in a paper, "Predictive Maintenance Strategy for Increasing the Life of Conveyor Systems,“ presented at the Congress on Conveyor Belts in Peru, in November 2015, preventive maintenance is safer and three times less costly than reactive maintenance.
- **LOTO / BOTO**
  Strict adherence to de-energization of the conveyor before cleaning and service is a basic safety tenet that has proven to reduce injuries and fatalities.
- **Root Cause Analysis**
  Management must move swiftly to identify and correct root causes and not accept excuses or incident reports that only blame workers for the majority of accidents.
- **Access**
  Access is the key to fast, effective, and safe conveyor cleaning and maintenance.
- **Safety by Design**
  It is well established that the best way to deal with a hazard is to eliminate it by design. Even if the facility does not use safe-to-service equipment to perform maintenance while the belt is running, equipment designed to be safe-to-service will be faster and safer to service.

3

- ❏ When conveyors are arranged in a series, do all automatically stop whenever one stops?
- ❏ Are conveyors equipped with emergency stop controls that require manual resetting before resuming conveyor operation?
- ❏ Are clearly marked, unobstructed emergency stop buttons or pull cords installed within easy reach of workers?
- ❏ Are continuously accessible conveyor belts provided with emergency stop cables that extend the entire length of the conveyor belt to allow access to the cable from any point along the belt?
- ❏ Are only trained individuals allowed to operate conveyors and only trained, authorized staff to perform maintenance?
- ❏ Are employees prohibited from riding on conveyors?
- ❏ Are employees instructed to cross over or under conveyors only at properly designed and safeguarded passageways?
- ❏ Are employees prohibited from wearing loose clothing or jewelry while working with or near conveyors?
- ❏ Is servicing and maintenance performed only under a Lockout/Tagout program?

- **5S**
  A clean and organized workplace is safe and efficient. Practice the 5S program of Sort, Straighten, Shine, Standardize, and Sustain.

Figure 23.11.

A key to keeping conveyors safe for workers is to follow established safety guidelines and regulations.

CLOSING THOUGHTS
Safe Work Means Safe Workers

A key to keeping conveyors safe for workers is to follow rules and regulations. (**Figure 23.11.**)

While conveyors can be designed for greater safety, guarded better, and maintained properly, it is still incumbent on those who will be working on and around them to work safely. The workers must take responsibilities for their own well-being—as well as for the well-being of others—through the use of safe techniques and procedures.

The establishment of clear and simple general safety rules, against which workers can test both routine and unique operating, cleaning, and maintenance situations, is an important step in working safely. Ultimately, management has the responsibility for creating and maintaining a safety culture. ⚠

3

Chapter 24 Conveyors, Fugitive Material, and Cleanup

3

INTRODUCTION

The Problem of Fugitive Material

One of the problems of belt conveyors carrying bulk materials is that the cargo—by definition, loose and unconfined lumps and fines—can escape from the materials-handling system. And these fugitive materials can lead to safety problems.

Fugitive materials can lead directly to accidents, through injuries to workers who are hit with lumps falling or thrown from overhead conveyors, or who suffer slip, trip, or fall incidents on a path or walkway that is slippery or obstructed with an accumulation of material. Around the conveyor it is well known many accidents and injuries are related to cleaning fugitive materials.

In the United States, the Occupational Safety and Health Administration (OSHA) says,

> Slips, trips, and falls constitute the majority of general industry accidents.

> They cause 15% of all accidental deaths, and are second only to motor vehicles as a cause of fatalities.

On its website, the National Floor Safety Institute (NFSI) points out that while slips and falls do not constitute a primary cause of fatal occupational injuries, they do “represent the primary cause of lost days from work.” And this type of incident can be costly. The NFSI website notes, “According to Workers Compensation statistics from ITT-Hartford Insurance Company, falls account for 16% of all claims and 26% of all costs.”

Belt Conveyors as a Source for Fugitive Material

There are several sources of fugitive materials in a plant, such as from leaking bins, uncovered hoppers, stockpiles, and malfunctioning dust collection systems. But belt conveyors are a major source of a plant’s problems with fugitive materials.

Escaped material can often be found at return idlers, tail pulleys, takeup pulleys, and transfer points. Material escapes from conveyors in several ways.

There is carryback—that is, cargo that sticks to the belt past the discharge point and then drops off along the conveyor return, often as the belt is ‘bounced’ over return idlers.

There is spillage, the material that falls off the side of the belt, commonly at transfer points where the forces of loading push lumps and fines out the sides of the belt under the skirtboard, where belt sag, due to inadequate belt support and failing edge seals, opens gaps. It can also escape off the back or tail of conveyors, particularly on inclined belts. Spillage also can fall off at any point along the conveyor as it travels from loading point to discharge, at points where equipment changes, or unanticipated forces push material off the side. Accumulations of material are often seen along the belt at the points near the discharge where a troughed belt flattens in preparation to unload its cargo and go around the head pulley. Material spillage can also be found outside transfer chutes where blockages and surges in material flow lead to a sudden overload of material that overwhelms the chute’s capacity. Large amounts of material can leak from small openings in the chutes. This material rains down and accumulates on equipment and walkways.

And finally, there is dust, the fine particles that are carried off the cargo by the air currents encountered in the loading of material, or as the belt moves along its path. Because it is airborne, dust can travel and accumulate anywhere in the plant, often well away from its sources in the conveyor.

Economic advantages of cleanup include reduction in dust, better operation of the plant, more efficient work by employees, less occupational disease, and fewer accidents from fugitive material problems.

The fugitive material can be minimized if worn chutes, skirtboards, and other causes of spillage are reported and corrected. Effective belt-cleaning systems also reduce the cleanup job around conveyor systems. Maintenance by a well-staffed and trained workforce is key in controlling fugitive materials.

In general, hazards will be reduced, and money can be saved if the escape of material can be minimized.

Minimizing fugitive material will reduce cleanup requirements and so reduce the potential for worker injuries.

3

The Hazards of Cleanup

But what is as dangerous as the presence of fugitive material—through slips and falls of workers and falling material hitting workers—is the cleanup of fugitive material. The need to clean around the conveyor brings workers into close proximity with conveyors. Due to the requirements of production, many of these conveyors remain in operation while the cleaning is taking place. (**Figure 24.1.**)

It is noted that many accidents around belt conveyors occur when workers are in the vicinity of the conveyor for cleanup or maintenance. As Todd Swinderman noted in a paper, *Conveyor Design for Safety and Maintenance*, presented at the 2015 SME Annual Meeting, "Approximately 33% of all fatal conveyor accidents occur while cleaning spillage and carryback under and around conveyors."

Other sources note the danger of performing cleanup around conveyors. For example, *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*, jointly produced by Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) and Commission des normes, de l'équité, de la santé et de la sécurité du travail (CNESST), both of Quebec, reported that of serious or fatal accidents, "A large number of these accidents occurred during cleaning (30%) … of or near a conveyor belt in motion."

The document's "Table 1-2 Serious or Fatal Accidents by Worker Activity" included these figures:

> Work activity when accident occurred, included:
>
> 23% Cleaning a drum or cleaning another part of the conveyor
>
> 7% Cleaning around or under the conveyor

The need to clean—to remove the accumulations of dust, spillage, and carryback from the ground and equipment around the belt conveyor system—poses risks for workers, whether they are plant employees or contract personnel. It puts workers in the vicinity of conveyor systems that are commonly operating during the cleanup work. The workers can use long-handled tools—shovels, scrapers, and brooms—to reach around and under equipment to collect and move the material from one place to another. (**Figure 24.2.**)

Fugitive material leads to accidents in another way, with perhaps greater risks to workers. The escape of cargo materials and the resulting accumulation along the conveyor(s) leads to the continuous labor and cost of attempts to clean areas, either to recover the lost material or merely to preserve the life of the equipment. Because of many plants' need to continue to operate with minimum downtime, the need to clean up puts workers in close proximity with working conveyors. This increases the risk of injury to those workers.

In its Data Sheet I-570 *Belt conveyors for bulk materials Part II: Operations*, the National Safety Council of the United States explains it this way:

Figure 24.1

Many conveyors remain in operation while cleanup work is performed nearby.

Figure 24.2

The use of long-handled tools around operating conveyors can multiply the risks for workers performing cleanup work.

> Improper cleanup, especially of [ground or] decking under the conveyors, is one of the most frequent causes of accidents. Typically, in an accident, a worker will be facing against the direction of belt travel and may tap the shovel on the belt when placing spillage back on the belt. If, at that moment, a splice in the belt meets the shovel, the shovel may catch in the splice and force the worker back into the conveyor. The worker may then catch an arm between the rollers and the belt, causing a possible serious injury.

An article in the Surface Mining Section of *Mining Annual Review 1995* summed it up:

> In the past 10 years in the U.K. there have been nine fatal conveyor accidents. Of these eight happened during repairs or cleaning up of spillage around drums [pulleys] and only one accident occurred as a result of inadequate guarding. Priority to spillage prevention would have resulted in some of these fatalities being avoided.

Minimizing the fugitive material will reduce cleanup requirements, and so reduce the potential for worker injuries.

REGULATIONS AND STANDARDS

While there are no standards that specifically require cleaning take place around conveyors, there are many standards and regulations that state plants must maintain suitable housekeeping to assure worker safety. These housekeeping standards are generally more carefully specified in regulations covering coal mines, where the risks of dust-related fire and explosion are significant.

Many jurisdictions spell out as a legal requirement or as a best practice that no cleaning of or around the conveyor is permitted while the conveyor is in operation unless it can be done safely.

Australia

Australian standard *AS/NZS 4024.3610 Safety of machinery – Conveyors*

The Blame Game: Who is Responsible for Fugitive Material?

An all-too-common conversation between the maintenance department and the operations personnel goes as follows:

Maintenance: *'If you clean the area we will fix the problem.'*

Operations: *'If you would maintain the equipment, we won't have so much fugitive material. Then we wouldn't have so much downtime and cleanup expense.'*

The maintenance department says the operations department is overloading the belt causing spillage.

The operations department says if the belt tracked straight, it would not spill.

And it goes on …

These circular arguments are as much a result of the organization's training and staffing of departments as they are the lack of either cleaning or maintenance. A conveyor is a system and changes in operations or maintenance will have an effect on the way the conveyor behaves including its release of fugitive material. Operators and maintenance staff need training in how changes affect the operation and how to find and correct the root cause of the problems.

The worst case—and by far the most common organizational structure—is when different departments are responsible for cleanup and maintenance. Then no one is accountable. Fingers point but the problem does not get solved. To improve accountability, both cleaning and maintenance activities should fall under a single department or be outsourced to a single supplier.

It is well documented that a clean facility will be safer and more productive. When production and maintenance departments cooperate and conveyors are designed or modified to reduce fugitive materials, great improvements in safety and production can be made.

– *General requirements* discusses the need to design the conveyor system to facilitate cleaning in section 2.4.4.1 Design for cleaning and inspection.

Noting that the removal of fugitive material is important to worker safety and fire prevention, the standard specifies the conveyor system should be designed to allow for safe cleaning around the points where it is anticipated that fugitive material will occur, such as crushers and conveyor loading and transfer chutes.

The *AS/NZS 4024.3610* standard also notes that where recovery of the fugitive material is required, the conveyor should incorporate a safe place or method where the material can be returned to the cargo, such as a chute where workers are isolated from exposure to moving parts.

The Australian and New Zealand standard for bulk-material conveyors *AS/NZS 4024.3611 Safety of machinery – Conveyors – Belt conveyors for bulk materials handling* cites in several places the need to clean and the dangers which arise from cleaning, without offering specific regulations or remedies.

To prevent accumulated material from creating a hazard, *AS/NZS 4024.3611* does specify in section 2.3.3 that clearances of not less than 300 millimeters [≈12 in.] above the floor to the underside of the belt and not less than 150 millimeters [≈6 in.] from rotating parts—that is, idlers and pulleys—to the floor shall be maintained for the removal of accumulated material.

Brazil

Brazilian standard *NR-22 – Safety and Occupational Health in Mining* specifies in clause 22.8.10:

> Any cleaning or maintenance work on belt conveyors shall only be performed with the equipment stopped and locked, except when cleaning with water jet or other method, in which case suitable protection devices against accidental contact with moving parts by the worker must be installed.

Canada

The best practices guideline, *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*, notes in Table 2-4 Safeguards for Maintenance Activities that disposal of material recovered on the belt is:

> ... authorized at all times as long as the danger zone remains protected by a guard. Particular attention should be paid to the space under an inclined belt located less than 2.5 m [≈98.5 in.] from the floor (belt risk analysis).
>
> … Lockout if the danger zone is not protected with a guard.

The table also notes, "Should the removal of material accumulation from an operating conveyor become frequent, consider installing an operator work station."

In its clause 372, Quebec's *Regulation respecting occupational health and safety in mines* specifies:

> It is prohibited to clean or inspect a component of a moving conveyor unless the process used does not require any handling that may cause a worker to come into contact with a moving element.

The *Health, Safety, and Reclamation Code for Mines in British Columbia* notes in Part 4.4.16 Conveyor Belts:

> (8) Servicing, or cleaning up spillage, on or around a moving conveyor belt shall only be carried out
>
> (a) where the conveyor system is so constructed that the work can be done safely and without removing any protective fences or guards, and
>
> (b) by persons who have been fully trained and authorized by the manager to do the work.
>
> (9) When it is necessary to remove protective fences or guards for servicing or cleanup, the conveyor shall be stopped and locked out in accordance with sections 4.11.1 to 4.11.7 of this code.
>
> (10) All guards or fences removed during cleanup or servicing shall be replaced before the locks are removed and the conveyor is started.
>
> (11) The manager shall develop safe work procedures for any work near moving conveyors and submit any major or significant changes to established safe work procedures to the chief inspector for approval and these procedures shall
>
> (a) address specific problems associated with each conveyor at the mine and indicate the speed at which each conveyor travels, and
>
> (b) for cleanup of spillage, include a safe procedure or mechanism for return of material to a moving belt, and a procedure or mechanism to allow the removal of materials lying below the conveyor that protects persons from contact with the moving parts of the conveyor and any material that may fall from the conveyor.

In clause 54 Preventive cleaning, Quebec's *Regulation respecting occupational health and safety* requires:

> All rooms where combustible dusts are generated shall be cleaned as often as necessary to prevent the accumulation of dusts on floors, beams, equipment, and machines, in quantities that can present a fire or explosion hazard.

In the *Occupational Health and Safety Act, Revised Regulations of Ontario 1990*, Regulation 854 Mines and Mining Plants, clause 266, it says:

> Where dust or other material is likely to cause a hazard by becoming airborne, the dust or other material, shall be removed with a minimum of delay by,
>
> (a) vacuuming;
>
> (b) wet sweeping;
>
> (c) wet shoveling; or
>
> (d) other suitable means.

South Africa

The *Safety Around Belt Conveyors* guideline published in 2016 by the Conveyor Manufacturers Association (CMA) of South Africa Ltd, section 4.1 Safety Requirements for Maintenance includes:

> The prohibition of work on moving machinery relates to tasks such as belt cleaning, house-keeping and the removal of spillage at localised points. Where build-up of carry-back material occurs on the face of pulleys and idler shells, the removal of this build-up is only permitted when the conveyor system has stopped and been safely locked out.

The following are excepts distilled from South Africa's *Mine Health and Safety Act 29, 1996* (as revised in 2013) and the CMA's *Safety Around Belt Conveyors* guideline included in Appendix A.

An employer must ensure:

(a) the designated sections of a conveyor belt installation are to be guarded, as per regulation 8.8(4) and not cleaned when any of its parts are in motion; provided that washing with pressurized water from a safe distance may be carried out, subject to regulation 8.9(1)(i);

(b) the power supply and all sources of stored energy of a stationary conveyor belt installation are isolated, made safe and locked-out during either repairs, maintenance, or cleaning of spillage in the designated sections; provided the alignment and training of a conveyor belt installation may be carried out whilst the belt is in motion …

(i) only persons authorised to do so by the employer operate, maintain, clean and repair a conveyor belt installation; and provided that any routine cleaning outside the designated sections of the conveyor section of the belt is carried out in accordance with a procedure prepared and implemented for this purpose.

The Act defines the designated sections as the drive section, takeup tension section, snub pulley sections, transfer point sections and tail pulley sections.

The Venetia Mine of De Beers Consolidated Mines offers some rules for cleaning in Revision 2 of its *Mandatory Code of Practice for the Safe Use of Conveyor Belt Installations for the Transportation of Minerals, Material or Personnel*. Section 8.5.1 Conveyor Belt Installation Safety Rules includes the instruction:

> No cleaning operations of spillage on conveyor deck plates, near any rotating pulley or idler may be carried out where physical contact can be made with any cleaning tool while the conveyor is in operation.

In 8.3.4 Installation of Guards, the code of practice continues:

> Safety guards may only be removed for purposes of cleaning, maintenance, repair and testing only. Removal of safety guards shall only be done after the conveyor belt installation has been de-energised and locked out in accordance with the De-energise, Isolate, Test, Lock-out and Make-safe policy.

> Guards shall be re-installed before the conveyor belt is put back to operation.

The document further emphasizes this point in 8.3.25.7 Duties of Shift Ore Processing Foremen Supervisors and Engineering Foremen, which requires the training of operators to:

> Ensure that safety guards are only removed for cleaning purposes or maintenance and this is done only after the conveyor belt system has been de-energised and locked out. And that the belt is not started until all guards are reinstalled, except under testing purposes (for example belt training).

United States

Section 5.2(c) of *American Society of Mechanical Engineers (ASME) B20.1-2015 Safety Standard for Conveyors and Related Equipment* states, "No maintenance or service shall be performed when a conveyor is in operation except as provided in paras. 5.3 and 5.4."

Paragraphs 5.3 Lubrication and 5.4 Adjustment or Maintenance During Operation each state that when the conveyor is in operation, the procedure identified in the paragraph title shall only be performed by "trained and qualified personnel who are aware of the hazard of the conveyor."

OSHA 1910.22(a) has a general housekeeping standard in *30 CFR 1910.22(a)*, noting: "All places of employment, passageways, storerooms, and service rooms shall be kept clean and orderly and in a sanitary condition."

The Mine Safety and Health Administration (MSHA) has similar general housekeeping standards, noting in *30 CFR 56/57.20003 Housekeeping* that at all mining operations:

> (a) Workplaces, passageways, storerooms, and service rooms shall be kept clean and orderly;
>
> (b) The floor of every workplace shall be maintained in a clean and, so far as possible, dry condition.
>
> Where wet processes are used, drainage shall be maintained, and false floors, platforms, mats, or other dry standing places shall be provided where practicable.

In *30 CFR 77.205* (b) Travelways at surface installations, it requires:

> (b) Travelways and platforms or other means of access to areas where persons are required to travel or work, shall be kept clear of all extraneous material and other stumbling or slipping hazards.

MSHA regulations in *30 CFR 56/57.14202* do specifically forbid the manual cleaning of conveyor pulleys while the conveyor is in motion.

In addition, MSHA's coal mining regulations include requirements for the removal of accumulations of coal dust. As noted in MSHA's *Program Information Bulletin P10-18*:

> MSHA's accumulation of combustible materials standard at 30 C.F.R. section 75.400 requires that coal dust, including float coal dust, loose coal and other combustible materials are cleaned up and not permitted to accumulate in active workings, or on diesel-powered equipment and electric equipment therein. In addition, 30 C.F.R. section 75.400-2 requires that mine operators establish and maintain a program for regular cleanup and removal of accumulations of coal and float coal dusts, loose coal, and other combustibles. Both standards are designed to prevent accumulations of combustible materials and reduce the danger of a mine fire or explosion.

Making Cleanup Safe

The first tip to making cleanup around belt conveyors safe is to shut down and lock out the conveyor when the cleanup is to take place. (**Figure 24.3.**) (**See Chapter 23 Working Safely Around Belt Conveyors.**)

But in many cases, workers are sent to work around moving conveyors. The conveyors are left running to keep production on schedule, and/or to simplify the removal of the cleaned materials. If, due to production schedules or other constraints, it is not practical to lock out the conveyor, then the following safe cleanup practices, provided by the National Safety Council in their *NSC Data Sheet I-570*, should apply:

- Do not clean under or near moving equipment when visibility is poor. Notify the supervisor of existing conditions and hazards and then proceed as instructed.

Figure 24.3.

Fugitive material creates safety problems because cleanup often brings workers into close proximity with operating conveyors.

- Workers who clean up spills around conveyors must be trained to follow safe cleanup practices.
- When cleaning overhead conveyor catwalks, or decking, or doing overhead repair where there is a danger of falling material, the "fall area"—the area below the overhead structures—should be cordoned off and danger signs placed where hazards exist. In addition, an observer should be stationed at ground level to warn other personnel to stand clear.
- Return fugitive materials to a moving conveyor belt only at positions specially designed and guarded to allow safe loading of the fugitive materials onto the moving belt. Generally a hopper station loaded by skid-steer or loader is preferred over manual return of fugitive materials to a moving conveyor belt. Shoveling onto a moving belt other than at a specifically designed loading station should be considered unsafe practices in today's world.

Shoveling Fugitive Materials

Probably the most common cleanup task is the shoveling of fugitive material. (**Figure 24.4.**) According to the Australia Mining and Quarrying Occupational Health and Safety Committee *Guidelines for Shovel Design & Use*, the risks of shoveling include:

The Right Tool for the Job

Using the right shovel can make the cleanup job easier and safer for the worker. According to the Canadian Centre for Occupational Health and Safety document *OSH Answers Fact Sheet: Shoveling*, the following are guidelines for selecting the proper tools:

- In general, when the blade is placed on the ground, the total length (blade plus shaft and handle) should be approximately to elbow height (when arms are at your side).
- Shovels with long shafts provide more leverage, but increase the risk of accidental contact for rolling components or moving parts.
- Shorter shovels with 'D' handles allow the worker to apply more force from above. However, 'D' handles should not be used around moving conveyors.
- Long-handled shovels can be safer, except where there is restricted clearance. A longer handle will reduce the chance of worker contact with pulleys and other moving components. Make sure the shovel is not too long that it could get caught in a pinch point between the belting and an idler.

- Repetitive extended reach forward—i.e. shoveling under conveyors—increases the strain on the lower back.
- Highly repetitive shoveling—i.e., not enough job rotation to vary a worker's tasks during the work shift—increases accumulated fatigue.
- Overloading the shovel—i.e., lifting too much material, particularly with longer shafted shovels, placing too much leverage and strain on the worker.
- Poor shoveling techniques—i.e., throwing the material behind the operator—causes excessive twisting of the worker's spine.

Considerations to control the risks of the shoveling include:

- Can the shoveling task be eliminated by containing the material and not dropping it on the ground?

Figure 24.4

The most common cleanup task is shoveling of fugitive material, which is often done by the youngest, or most recently-hired employee.

How much can a worker shovel?

The conventional wisdom—or perhaps it is folklore— says an individual worker can shovel one ton of material in an hour. Although whether this is actual, measured output, an apocryphal story whose roots are lost in the mists of time, or just a convenient 'rounding' of desired performance that allows easy multiplication into other equations of workload and productivity is unknown.

An article published in *Cassier's Engineering Monthly* in 1917 reported: "A man transferring coal from a barge to the bunkers of another vessel, if unaided by machinery, can by the help of a shovel and basket convey one ton of coal an hour."

According to the Canadian *OSH Fact Sheet*, much more recently, Kodak included information on shoveling in its "Kodak's Ergonomic Design for People at Work – 2nd Edition", published by John Wiley & Sons, Hoboken, NJ, in 2004. The Kodak work summarized studies showing that a 15-minute shoveling task can be done at a total load of 750 kilograms [1,650 lb] if the placement of the material was low and not very precise. If it is above 102 centimeters [40 in.] and not precise, 530 kilograms [1,165 lb] can be transferred in 15 minutes, and 245 kg [535 lb] if it is low but needs precision control.

The *OSH Answers Fact Sheet: Shovelling* from the Canadian Centre for Occupational Health and Safety offered this guidance:

> The most efficient shoveling rate is about 18-21 scoops per minute. However, fatigue builds up over a short time at this rate. Therefore, the recommended rate for continuous shoveling tasks is usually considered to be around 15 scoops per minute. Tasks involving continuous shoveling at this rate should not be carried on longer than fifteen minutes at a time. The shoveling rate will also depend on how easily the shovel can be inserted into the material being moved (e.g., grain, snow, gravel, compacted earth).

It seems obvious that if the material is scattered and piled randomly around a conveyor, it will take more time to shovel it up than the shoveling of an accessible and unified (if loosely piled) stockpile.

The Canadian *Shovelling Fact Sheet* continues:

> Throw height should not exceed 1.3 meters (approximately 4 feet). The optimal throw distance is slightly over 1 metre (about 3 feet). The load should be reduced if the task requires a longer throw.

It also noted:

> Since most shoveling is done outdoors, consideration for the prevailing conditions is very important. In the more extreme conditions such as very hot and humid, or very cold and windy, 15 minutes of shoveling should be followed by 15 minutes of rest.

- Can the manual shoveling be re-engineered; can the process be mechanized?
- Select the right shovel for ease of use and to minimize the risk of injury. Things to consider: blade size, flat or angled blade, blade sharpness, shaft length and material, handle shape and bend, and grip type.

Figure 24.5.

Shovels with 'D-handles' are unsafe because of the chance a workers hand will be trapped in the handle if the shovel is caught in the machinery.

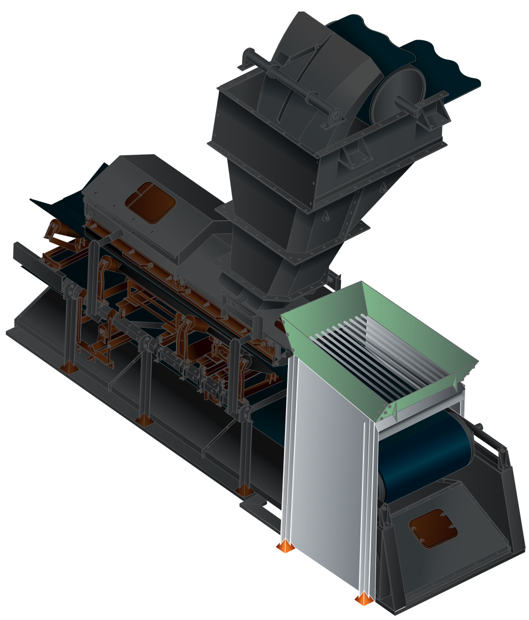


Figure 24.6.

Material cleaned from the plant should be returned to the conveyor at a properly guarded reloading hopper near the conveyor trail.

Safe Shoveling

The first step to safe cleaning is shoveling safely. Shoveling is strenuous work, especially for the heart and the back. A number of tips can improve shoveling technique and safety; they include:

1. Lock out the conveyor. If the cleaning cannot be done without removing the guards then the conveyor must be Locked Out / Tagged Out / Blocked Out / Tested Out (LOTO / BOTO).
2. If cleaning must be done while the conveyor is in operation, make sure all guards are in place and that collected material is only returned to the belt through a properly designed and guarded cleanup hopper.
3. If the guarding is inadequate to protect ALL nip points, then the conveyor must be LOTO / BOTO for cleanup. The guarding must be repaired or replaced immediately.
4. Do not used D-handle shovels. D-handle shovels can be more difficult to let go of, as the worker's hand is enclosed inside the enclosed 'D' grip. (**Figure 24.5.**)
5. Use proper technique to help assure effective, injury-free shoveling. Avoid back injuries by loading the shovel moderately. Be sure to have solid footing; establish a wide base of support with legs apart, knees bent, and back straight. Lift with the legs, not the back. Choke up on the shovel to keep weight close to the body; this encourages the worker to use the legs. Avoid twisting; move feet when turning, rather than twisting body.
6. If it is too far to throw comfortably, walk to where the material can be dumped.

Figure 24.7.

Comparison of the rate of cleaning using various techniques or tools.

Cleaning Rate	Minimum (metric tons/hour)	Default (metric tons/hour)	Maximum (metric tons/hour)
Manual Shoveling	0.50	1.00	1.50
Manual Fire Hose	1.00	2.00	3.00
Skid Steer	1.00	2.00	3.00
Front-End Loader	6.00	12.00	18.00
Vacuum Truck	15.00	25.00	35.00

Here, hold the arms close to the body; holding a shovelful with outstretched arms puts too much weight on the spine.

7. Be careful where material is thrown. Be conscious of the surroundings. Watch other workers and mobile equipment that might move to pinch, confine, or otherwise trap the cleanup crew. Watch for others working in nearby areas to avoid striking co-workers with materials.
8. Never clean alone—use the buddy system.

If the distance material is to be moved is greater than the optimal one-meter throw distance, then the material should be placed in a collecting pile or container of some kind, such as wheelbarrow, the scoop of a front-end loader, or a low-walled bin, that can then be collected and emptied by mechanical equipment.

If the collected material is to be returned to the belt by manual shoveling or dumping, the conveyor reloading zone should be built into the transfer point. Manual loading may be accomplished safely by incorporating an access door between the tail pulley and the loading chute of a properly guarded tail section. (**Figure 24.6.**) Material can also be returned onto the belt after the outbound end of the transfer-point skirtboard, or at other points where the belt is exposed, such as where it enters the conveyor discharge, as long as there is a specific loading point that is guarded against either the shovel or the person coming into accidental contact with the belt or any moving or rotating component.

Techniques and Technologies for Cleaning

Other equipment and techniques can be incorporated in the cleaning project, either as a supplement to or replacement for basic shovel work. These methods include high-pressure hoses, small excavators, and vacuum or sucker trucks. The rates for the amount of material moved or recovered for various cleanup methods are compared in **Figure 24.7**.

The following are tips for safe and efficient cleaning methods.

High-Pressure Hose

Where legal, high-pressure water sprays—such as a fire hose or a pressure washer—are often used to remove material accumulations. (**Figure 24.8.**) Here are some tips:

- Wear safety glasses or goggles.
- Set the hose pressure at a level that the workers can safely hold and move.
- To prevent the hose from whipping, use a secure grip, stand on the hose near the nozzle, turn on pressure slowly, and/or get a second worker to help maintain control of the hose.
- Use good posture, stand with feet apart, lean forward to brace against pressure. Do not stand with back toward open walkways or stairs. Do not climb or descend stairs while handling the hose under pressure.
- Know where the water is going. This is important during cleaning operations, so the spray does not affect other operations, personnel, or equipment. When the cleaning operation is complete, it is important the plant does not have trouble with emissions and releases of contaminated, untreated water.
- Start from the highest area and work down, washing platforms, walkways, and

Figure 24.8.

High pressure water sprays are often used to remove material accumulations.

3

other areas where there is an accumulation of material.

- Watch the spray. Avoid aiming at electrical junction boxes; do not aim nozzle at other workers.

The plant should be fitted with suitable drains or sumps during the plant design stage if it is intended that hose cleaning will be used. These systems will likely need retention ponds to prevent the uncontrolled discharge of contaminated water.

As a hose can become an entanglement or trip hazard around the conveyors, it may be advisable to install fire nozzle stations at fixed locations in the facility. With pivoting nozzles mounted in these stations, an operator would be able to direct water at spillage locations, without needing to drag a hose all around the plant.

Skid-Steer Loaders

Small front-end loaders—often called generically, 'skid steers' or 'bobcats'—are often used in conveyor cleaning operations. (**Figure 24.9.**) Skid-steer loaders are useful because they are smaller than full-size equipment and can maneuver in tight spaces such as underneath conveyors. The smaller equipment is also more economical to purchase and operate than full-size front-end loaders and bulldozers.

They typically have a bucket, but can be fitted with other attachments like a dozer blade, grader, or forklift to perform other duties in the plant. (**Figure 24.10.**)

While they are labor-saving devices, skid-steer loaders can also create risks for plant personnel. The National Institute for Occupational Safety and Health (NIOSH) found a number of fatalities associated with the use of skid-steer loaders.

According to the University of Nebraska Lincoln's *Safe Operating Procedure: Skid Steer Loaders*, these accidents are most often attributable to:

- Working or standing under a raised loader bucket
- Leaning out of the operator's compartment into the path of the moving lift arms
- Improper entering or exiting
- Rollovers

To avoid rollovers, drive straight up or down slopes, with the heavy end pointed uphill and the bucket lowered. Do not drive across steep slopes.

Tips for safely using skid-steer loaders in a plant cleaning operation include:

- Wear proper personal protective equipment (PPE) for the environment, including hard hat, safety glasses, and hearing protection. Wear the seat belt.
- Establish clearances before starting; know how wide the blade is and how tall the loader is when the blade or scoop is all the way up.

3

Figure 24.9.

Small loaders are often used in cleaning, as their compact size allows them to fit around and under the conveyor system.

Figure 24.10.

Small 'skid-steer' loaders can be fitted with attachments to improve cleaning operations.

Photo courtesy of the United States Mine Rescue Association.

Bobcat® is a registered trademark of Bobcat Company in the United States and various other countries; for information, visit bobcat.com

- Do not operate the loader in a manner that causes any wheel to leave the ground.
- Do not overload the bucket. Two trips are better than one accident.
- Carry the bucket low when transporting materials. Do not carry items that could fall or roll off.
- Check for co-workers before changing direction (especially before going in reverse).
- When driving, watch for walkers as well as other vehicles. Know where all pedestrians are before moving.
- If working with other employees in the vicinity—with a cleanup crew, for example—use the buddy system and have a dedicated 'spotter' for other personnel as well as obstructions and other hazards.

The following practices will minimize hazardous situations associated with operating and maintaining skid-steer loaders:

- Do not leave the operator's seat while the engine is on. Never attempt to activate the controls unless properly seated with the seatbelt fastened and the seat bar (if equipped) lowered.
- Keep all body parts inside the cab while operating a skid-steer loader.
- Never permit riders on the skid-steer loader, in the bucket or other attachment, or in the operator's compartment unless the compartment is designed to accommodate a second rider.
- Barricades or other warning devices must be used to divert traffic when skid-steer operations are in close proximity to pedestrian or vehicle traffic. Always keep bystanders a safe distance away from the work area.
- Follow the manufacturer's instructions for a skid-steer loader maintenance program.
- Never attempt maintenance or other work while its lift arms or attachments are raised without using an approved lift-arm support device. Replace protective guards and shields after repairs or service.
- Skid-steer operators should be properly trained. Train personnel on the proper inspection, use, maintenance, and repair of skid-steer loaders according to the manufacturer's instructions.

When working around a skid steer:

- Personnel working in close proximity to an operating skid-steer loader must wear a high-visibility safety vest.
- Be mindful of how quickly the skid-steer can change directions.

Vacuum Trucks

Another type of heavy equipment often seen in conveyor cleanup operations are vacuum trucks. These are often called 'air movers' in the industry—or more colloquially, 'sucker trucks.' But of course, they are not used because they can move air but rather move material. (**Figure 24.11.**)

They provide a powerful vacuum-cleaning action that will pull in solids, liquids, sludge, or slurry through hose lines typically 1 to 4 inches [≈25 to 100 mm] in diameter. They pull the material into a truck-mounted tank where the air is typically filtered and discharged, while the material is collected into a tank.

Care must be taken when working with or near the hose. The powerful sucking action of the vacuum hose lines can lead to a serious or fatal injury.

When used in cleaning operations, vacuum trucks need to move less than some other

Figure 24.11.

Vacuum trucks provide a powerful cleaning action to collect fugitive material.

equipment, such as skid-steer loaders. In most circumstances, the operator can move the hose end without having to move the truck itself. But, they are large pieces of equipment which—especially in the confines of an industrial setting—may have limited sight lines and visibility from the cab. So care must be taken when the truck needs to move to a new location.

Tips for working with or around a 'vac truck' in a conveyor cleaning operation include:

- Wear proper PPE for the environment and for the operation of this system (including hearing protection).
- Know the hazards associated with the material to be vacuumed.
- Know the equipment, including the emergency shutdown controls. Operators should be trained and authorized. Workers in the vicinity should also know the shutdown controls.
- Stay out of the tank; it is a confined space.
- Never back up a vacuum truck without having constant visual contact with a spotter. Always get out of the cab and look over the situation before backing up.

BEST PRACTICES
Conveyor Cleanup

The following are identified as Best Practices for the cleanup of fugitive material around belt conveyors:

Install and properly inspect, adjust, and maintain the systems to prevent or minimize fugitive material.

- Invest in systems to prevent the escape of fugitive materials such as dust, spillage, and carryback. There is a prompt and significant return on investments for those system which prevent the escape of fugitive material and thus reduce the expenditures for conveyor cleanup and component replacement.
- New systems can be designed to allow safe cleaning under the conveyor in areas of anticipated high accumulation of fugitive materials. In those areas the conveyor can be elevated and guarded to allow cleaning to be done safely and at less frequent intervals.

Follow proper shutdown practices when required to clean around belt conveyors.

- These include Lockout / Tagout / Blockout / Testout, as detailed in **Chapter 23 Working Around Belt Conveyors.**
- Use the buddy system.

Employ available technologies to replace or supplement manual cleaning.

- Use wash-down systems, skid-steer loaders, vacuum trucks, and other systems in keeping with budget and cleaning requirements to minimize labor. When using powered equipment, watch for other personnel working in the vicinity; use a spotter when moving.

Use proper work techniques when performing manual cleaning around belt conveyors.

- Use proper tools and techniques to reduce risks of injury.
- Whenever possible collect material in an area where it can be scooped up mechanically.
- Return material to a moving conveyor only at a properly guarded hopper designed to allow the safe return of material to the conveyor.

CLOSING THOUGHTS
Keeping it Clean, Keeping it Safe

The need for cleaning around belt conveyors puts workers in jeopardy as they are often required to work around moving conveyors. Even if the conveyors are not in operation, the accumulations of fugitive material pose risks in unstable platforms, uneven workways, and flying and falling materials. The keys are to first reduce the amount of material that escapes, and second, use proper techniques to collect and handle fugitive material efficiently and safely. (**Figure 24.12.**)

While technically not a fugitive material, cleaning buildup in discharge and dribble chutes resulting from accumulated fines can present significant dangers from falling masses of consolidated bulk materials and often requires confined space work and employee possession of a confined-space permit. ⚠

Figure 24.12.

A key to a safe conveyor is to reduce the amount of fugitive material that escapes, and then use proper techniques to clean the material that has escaped. A clean conveyor will be a safer conveyor.

3

Chapter 25 Blocking the Belt Against Motion

Thanks to Greg Westphall, Director of Engineering, Flexco, for consultation and review of this chapter.

Image courtesy of Flexco.

3

INTRODUCTION

The Risk of Unwanted Belt Motion

As already discussed in this volume, it is standard practice—indeed, it should be required procedure—that prior to performing work on or around belt conveyors, the drive system is de-energized. This includes lockout and tagout of the drive system of the belt conveyor, as well as any related equipment that might feed material into or out of the conveyor. This other equipment includes other conveyors, feeders, crushers, and the gates above gravity-feeding bins. In addition, access should be restricted to any load points that may be serviced by mobile equipment.

However, what is less commonly known is there remains the potential for belt motion—and the resultant risk of injury—even when a conveyor is properly locked out and tagged out. Belt conveyors have harmed and killed workers by moving even when the drive system has been de-energized.

As noted in the *Safety Around Belt Conveyors Guideline* published by the Conveyor Manufacturers Association of South Africa Limited,

> ... It is important to remember the danger presented by residual energy stored within the system and to address this adequately.
>
> Thus it is necessary to isolate the stored energy from the work area or to completely release all stored energy from the system, so that work can be performed in a safe environment.

How a Locked-Out Belt Can Move

In order to operate, the belting on a conveyor is placed under tension, both from the weight of the cargo loaded onto it and from the force of the drive system and the takeup system. These forces combine to create a tension that pulls the belt tight, and thus allows the drive system to move the belt through the structure.

Conveyor belting under tension is like a stretched rubber band. This stretching comes as the belt is placed under considerable forces. The amount of tension is based on factors such as belt geometry, belt material, drive and takeup specifications, and the amount of conveyed material on the incline or decline of the belt.

There are places along the conveyor system where the tensions can be considerably higher than other areas of the system. The position of the drive or braking system, takeup, incline or decline of the system, loaded portions of the belt, and whether the belt is moving or stopped determines where tensions are high and where they are lower.

These tensions allow the application of energy from the torque of the drive to the belt in the case of inclined conveyors, or from the load and by gravity to the belt for declined conveyors, in order to efficiently move the belt and its cargo. In the case of inclined conveyors, if there is inadequate tension present, there will be no movement or at least no efficient movement. Instead of moving through the conveyor structure, the belt will slip where it contacts the rotating components in the drive or braking system. In the case of declined conveyors, the tension created by the load and gravity is often used to generate power at the tail pulley. If the tension is inadequate at the tail, the belt will slip and the braking effect of the tail pulley via friction will allow the belt to slip.

The Legal Requirement to Block Equipment

As a noun, the term 'block' means an obstacle or obstruction, or as a verb, to make unsuitable for passage or progress by obstruction, to prevent normal function. (**Figure 25.1.**)

Many jurisdictions include the requirement that equipment that is undergoing maintenance be blocked to prevent movement. This is not explicitly a conveyor regulation, but rather is included in the requirements for general industrial (or mining) equipment.

For example, in the United States, the Mine Safety and Health Administration (MSHA) requires in *30 CFR 56/57.14105* that:

> Repairs or maintenance of machinery or equipment shall be performed only after the power is off, and the machinery or equipment is blocked against hazardous motion.

This is applicable for both Part 56 (for Surface Metal and Nonmetal Mines) and Part 57 (for Underground Metal and Nonmetal Mines).

Ontario's *Occupational Health and Safety Act (R.S.O. 1990)* has similar requirements

Figure 25.1.

The phrase 'blocking the belt' is used to describe the method of clamping the belt to prevent all movement.

Image courtesy of Flexco.

in Section 75: Maintenance and Repairs of Regulation 851 for Industrial Establishments. It requires that:

> A part of a machine, transmission machinery, device or thing shall be cleaned, oiled, adjusted, repaired, or have maintenance work performed on it only when, (b) any part that has been stopped and that may subsequently move and endanger a worker has been blocked to prevent its movement.

Beltcon Paper Discusses Fatalities from Unwanted Belt Motion

A 2013 paper, *Non-Gravity Take-up Technology*, by Alan Exton included a discussion of the hazards of stored energy and uncontrolled belt movement. The paper was presented as part of the Beltcon 17 Conference in South Africa.

Exton defines stored energy as:

> ... potential energy derived from the elasticity of the belt, that is stored in a belt strand within a conveyor system and if released, presents itself as an instantaneous danger to human life and equipment.

He then recounts two examples of fatalities resulting from this stored energy.

Example 1: Maintenance Accident (Figure 1.)

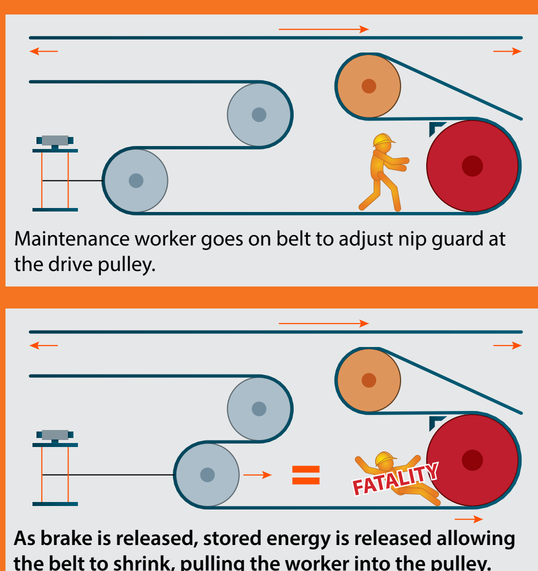


Figure 1.

A worker was adjusting a nip-point guard on the secondary drive pulley of a conveyor. The necessary risk assessments were completed, and the work was planned so it could be carried out safely. Meanwhile, additional workers were replacing idlers on the same conveyor. When the idler team finished the job, they released the brake on the takeup. Stored energy caused the belt to move forward, pulling the nip guard worker into the pulley. The result: a fatality.

Example 2: Tail Pulley Accident (Figure 2.)

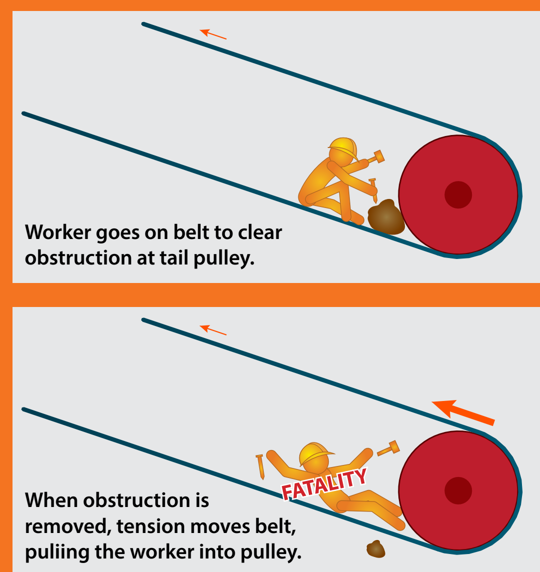


Figure 2.

A large rock is lodged between the tail pulley and the return strand of an inclined conveyor. This resulted in an electrical overload causing the drive to trip. A holdback on the head (drive) pulley prevented the carrying side from rolling back and so releasing the tension on the carrying strand of belt. A worker went between the strands at the tail pulley, intending to reduce the rock in size to allow its removal. Once the rock was sufficiently smaller, the tension on the two strands equalized, and the stored energy was released. The resulting movement of the belt pulled the worker into the pulley. The result: a fatality.

Both fatalities could have been prevented if the belts had been properly blocked.

In Exton's paper, stored energy is a topic that "requires permanent attention. …. A misunderstanding of this potential energy has proven to be LETHAL in our industry."

Assessing the Risk of Uncontrolled Motion

Even when a belt conveyor has been properly locked out and tagged out, there may still be significant amounts of tension or potential energy present in the system. This energy creates a risk of injury to personnel who are working on or around the conveyor.

It is important to note the distinction between *energy* and *power*. These terms are similar in meaning, but they cannot be used synonymously in all instances. The term *power* relates to kinetic energy or the energy of motion. Even when a conveyor has its power supply turned off and locked out, there may still be residual energy present. This energy is captured in the form of potential or stored energy from the pull of the counterweight, from the mass of the cargo on a loaded belt due to gravity, and from the tension stored in sections of a stretched, but not moving, belt.

Which way will the belt move?

In some circumstances it is difficult to predict in which direction a stalled or blocked belt will move when released. The included illustration helps explain the difficulty in judging the movement of a suddenly released belt, and so shows the need for blocking the belt to prevent unwanted movement and provide safety for workers.

The example was prepared using conveyor design software to assess belt tension and the effects of a blockage. The following example shows an inclined belt where the motor has stalled due to the blockage of rotation at one of the pulleys.

This sequence shows a Belt blocked at the tail pulley. A backstop is installed on the head pulley.

In the illustrations, the thicker the colored fill shown around the belt, the higher the tension in the belt. Tension is typically highest at the head and lowest at the tail due to the gravity load of the bulk material.

Figure 1: Green
The belt shows normal running tensions.

Figure 2: Orange
An obstruction blocks the tail pulley and the drive motor stalls and trips out. Tension (in the orange fill) is locked into the stalled and stretched belt as potential or stored energy. The belt is kept from moving backward from the load on the belt by a backstop.

Figure 3: Red
When the obstruction is removed, the tension in the system drops to a normal stopped level. The tail pulley now rotates clockwise, and the takeup will move up. In the immediate area of the blockage, the belt will also move in a clockwise direction until the stored energy (over-stretching) in the belt is relieved. This creates nip points between the in-running belt and the tail and takeup pulleys.

The amount of movement depends on the length of the belt (recovered stretch) and the actual amount of tension stored in the belt from the stopping of the motor by the obstruction.

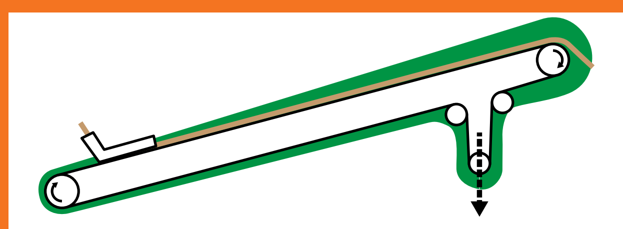


Figure 1.

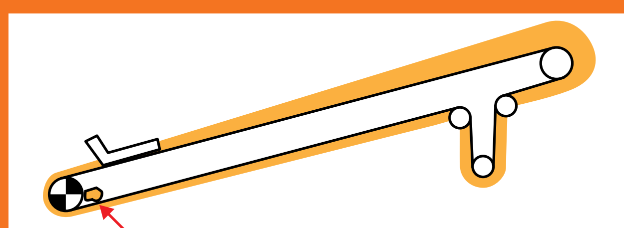


Figure 2.

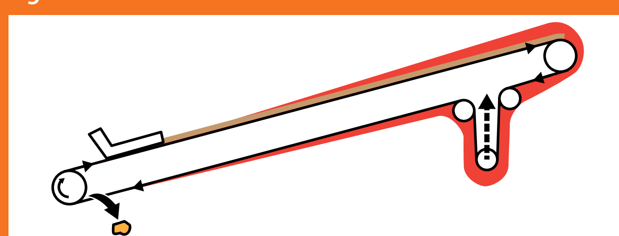


Figure 3.

3

In the case of a belt that is not endless due to a broken splice or that has been separated on purpose for repairs, there still can be potential energy stored in the hanging or inclined sections of belt.

The essential practices of lockout and tagout must be continued. But in addition, there will be many instances when the belt conveyor must be physically restrained from moving under its own stored energy. (**Figure 25.2.**)

Other Sources of Stored Energy

There are other sources of stored energy associated with a conveyor. Buildups of material in chutes and on structures can contain significant potential energy, and there have been numerous fatal accidents from falling materials while working inside of chutes. Traveling mechanisms such as trippers or stacker-reclaimers can move unexpectedly, causing the belt to move if it is not blocked. Accessories such as samplers or discharge plows can move unexpectedly during belt maintenance. Corroded or worn components or structures can give way from added loads while the belt is stopped but work is in progress.

Thus, it is necessary to isolate the stored energy from the belt and the surrounding work area or to completely release or block all stored energy from the system, so that work can be performed in a safe environment.

Figure 25.2.

To prevent inadvertent movement, the belt should be physically restrained.

Image courtesy of Flexco.

The blockout methodology uses 'brute force' mechanisms to physically prevent the belt from moving. The belt will not move because it is kept from moving by being held in one position.

Blocking the Belt

Despite the availability of various other—sometimes easier but often less successful—techniques, the best way to assure worker safety is to physically restrain the belt from moving. This is called 'blocking' the conveyor belt.

'Blockout' is the phrase to describe the activities that will physically restrain the belt so it cannot move. These procedures are applied in addition to the accepted lockout / tagout procedure which isolates the conveyor from its power supply.

The word 'blockout' is used because it fits well with other phrases such as lockout and tagout.

Some Not-So-Successful Methods

There are other techniques that can be used to reduce belt tension and eliminate the chance for uncontrolled belt motion. These techniques have only mixed results and consequently might not lead to safe conditions.

For example, properly installed brakes and backstops may help prevent this rollback. However, a plant should not rely on the backstops or brakes to prevent a belt from moving on its own. There have been instances when the belt has moved due to the internal tensions created by the belt stretch.

Another technique calls for the lifting of the conveyor's takeup counterweight. (**Figure 25.3.**) In essence, this method reduces the tension on the belt by reducing the pull of the takeup mechanism. But there are still other potential sources of tension on the belting, such as the stretch inherent in the belting itself, the weight of the belt, or the gravitational pull exerted by the weight of the cargo on the belt. While removing the pull of the counterweight may reduce the tension, it does not eliminate the potential for the other stored energy sources. Nor does it necessarily secure the belt against motion. Removing the pull of the counterweight alone is not sufficient to remove all the tension and force in the belt that can injure personnel.

Clamps, Chains, and Come-Alongs

Blocking the belt is performed using belt clamps in combination with chains and ratchet lever hoists (commonly called come-alongs) to physically restrain the belt. The intent is to prevent movement of the belting by securing it to a substantial member of the conveyor structure.

This task amounts to squeezing the belt between two bars that are compressed together. With the belt thus held, the clamps can then be attached (via chains and come-alongs) to the conveyor structure. (**Figure 25.4.**)

It is possible to block a belt using only clamps by wedging the clamps into the conveyor structure. However in that case, the clamp(s) must be wedged firmly into the structure—a process that is harder to both install and remove efficiently and safely, and which poses a greater risk of accidental release.

It is common to block the belt using chocks when working on pulley lagging, removing buildup or material wedged between the belt and pulley. However in this case, the chocks must be wedged firmly into both the in-running nip points and the outgoing nip points. As a result, they may only stop the rotation but not the belt movement at the nip, and they are difficult to install and remove safely.

Chocks or wedges can also be used to secure the belt against fixed structural members such as beams or cross braces, but the amount of clamping force is unknown and relying on point contact is an unreliable method.

Clamps

Clamps are used as a method to lock the belt in place by securing the belt—in one or more positions, but usually on both sides of the section of belt being worked upon—to the conveyor structure. If the amount of tension or other forces on the belt are less than the clamping force applied to it and the strength of the framework is great enough to resist the pull against it, the belt cannot move.

Most clamps operate by tightening two engineered cross-belt beams down to the belt, holding the belt securely between the beams. In some lighter-duty applications, an alternative belt clamp can be affixed to the outside edges of the belt. In either case, the clamps must be capable of creating sufficient friction across a large enough clamping area to restrain belt movement.

The *Safety Around Belt Conveyors* guideline published by the Conveyor Manufacturers Association of South Africa Limited notes:

> Where belt clamps are utilised, these must be securely anchored to the structure. This applies to both permanent clamps and temporary belt pulling clamps. Belt clamps must be inspected and tested before attachment to ensure that they are able to withstand the belt tensions in the localised area.

Figure 25.3.

Lifting of the takeup counterweight alone is not sufficient to completely remove the risk of belt movement.

Image courtesy of the United States Mine Rescue Association.

Figure 25.4.

Blocking the belt should be performed by securing the belt between clamps, which in turn are connected to the conveyor structure.

Image courtesy of Flexco.

The clamp specification of the Conveyor Manufacturers Association of South Africa Limited published as *Clamps for Belt Conveyors (MC01 Rev 01)* lists two types of belt clamps: fixed or belt-restraining clamps, and portable or pulling clamps. The permanent clamps are designed into the conveyor structure and are usually hydraulic shuttle systems with two sets of moving clamps. To move the belt, one clamp is loosened and one clamp engaged. The belt is pulled forward and clamped, festooning a short section of belt. (**Figure 25.5.**) The belt can then be spliced or repaired. The same system can be used to feed new belt onto the conveyor.

Either type can be used for the purposes of blocking a belt, providing it can be securely fixed to the conveyor structure and has sufficient blocking capacity. Consequently, the clamps must be solidly constructed and in sound condition.

Come-Alongs

A come-along is a portable, hand-operated ratchet lever winch used for stretching, lifting, and lowering objects. Also called lever chain hoists, come-alongs are convenient and portable enough to use in almost any situation. They are compact, light, and very easy to rig into position. They are small enough to carry in one hand and often weigh less than 20 pounds [≈9 kg] each.

In a belt-blocking operation, come-alongs can be used to connect, secure, and tighten the belt clamp to the conveyor structure. By using a pair of come-alongs—one on each side of the conveyor—the clamps (and hence the belting) can be secured evenly to the conveyor structure.

Figure 25.5.

To allow the belt to be spliced or repaired, one clamp is loosened and one clamp engaged. The belt is pulled forward and re-clamped, festooning a short section.

Image courtesy of Flexco.

Since the come-along is being used to provide safety to humans, they must be of adequate strength and be inspected to ensure they are fit for the intended use of blocking the belt movement.

Chains and Chain Slings

Chains, straps, or wire-rope cables are commonly used to connect the clamps (which hold the belt) to the conveyor structure. Even though these connecting methods are not being used in a typical lifting situation, they must be of adequate working strength—defined as 1/10th their breaking strength—and inspected to the same standards as wire-rope cables, slings, or chains used for lifting and hoisting.

A chain sling—that is, the combination of chain, hooks, and links that will serve as the connection between the belt clamp and the come-along and/or the conveyor structure—must be manufactured from alloy steel. They come in a variety of lengths and combinations of hooks and components, depending on the application.

Every chain or chain sling is only as strong as its weakest link, so it is very important that every component of the sling meets the standards for rated capacity, which is called the working load limit (WLL). The WLL is determined by the 'grade' of the chain and its components. For overhead lifting, only high-grade alloy steel chains and components may be used. These devices must meet a variety of strict quality standards such as minimum breaking strength, fatigue testing, and heat resistance. All chains and components must be marked by the manufacturer with a grade from which the load rating can be determined.

The most commonly used chains for overhead lifting are rated at Grade 80; however, the industry is moving to the stronger and safer Grade 100 and Grade 120 chains.

Attachments, such as hooks and rings, links, and couplings should have a rated capacity at least equal to that of the alloy-steel chain with which they are used. All chains and components must be marked by the manufacturer with a grade from which the load rating can be determined. It is important to note that a number of factors such as lifting at an angle, wrapping the chain around a load, or extreme temperature substantially reduces the WLL of the sling. These factors must be considered when determining what type of sling is necessary to lift a load.

Chain slings come in a variety of lengths and combinations of hooks and components, depending on the lifting application. (**Figure 25.6.**) The National Association of Chain Manufacturers have specified a variety of chain testing and safety standards, including the American Society of Mechanical Engineers *ASME B30.9* and *ASTM-A906*. Any chain sling used for lifting must have suitable characteristics for the type of load hitch and environment and must be in accordance with *ASME B30.9*, Sections 9-1.5 and 9-1.8.

The use of chain slings or sling components is governed by United States Department of Labor Occupational Safety and Health Administration (OSHA) regulations. In particular, *29 CFR 1910.184* governs the operation and usage of alloy-steel chain slings and sling components. In other areas, consult the local standards-issuing and regulatory bodies.

It should be noted that the come-along, chain, and clamps form a system. All components should have similar capacity ratings. Otherwise, the lowest-rated component becomes the 'weak link' in the system, and prone to failure. Matching the clamp capacity to the come-along capacity prevents tensioning of the clamps beyond their design limitations.

Proper Blocking Procedures

In the preferred method, the clamp spans across the entire width of the conveyor belt.

There are two types of clamps, ones that require some movement of the belt to engage the clamps, and a second that does not require movement of the belt for the clamps to engage.

The clamps that require movement of the belt to engage are cam- or scissor-style. These clamps apply more clamping pressure as the tension from the come-along increases. Matching the clamp capacity to the capacity of the come-along is important to prevent overloading the clamp or crushing the belt.

The type that does not require some movement of the belt are the vise-style clamps. With the vise-style clamps, the pulling capacity depends upon the torque applied to the clamp screws. The vice style is often misused when releasing the tension in the belt by keeping the come-along engaged as the vice screws are loosened, allowing the belt to slip through the clamp. The proper procedure is to simultaneously release or play out the come-alongs.

The clamps should be construction of high-grade steel or aluminum components that are rugged and lightweight, making for easy transportation and assembly.

It is critical that the blocking equipment be properly checked prior to use. Inspect the clamps and the rest of the equipment for damage or missing components.

Prior to attaching the clamps, clean off any accumulated material that might interfere with the clamping surface's ability to hold the belt securely. Similarly, make sure the belt is clean of foreign substances such as oil, water, or cargo material at the point where the clamp(s) will be attached.

Clamps are typically affixed to the belting by tightening screws/bolts, which in turn forces the

Figure 25.6.

Chains or chin slings are commonly used to secure the belt clamp to the conveyor structure.

Image courtesy of Flexco.

3

top bar down toward the bottom bar, pinching the belt between. Some lighter-duty belt clamps are tightened with blows from a hammer.

The belt clamp should be secured to a structural member of the conveyor capable of restraining the expected forces. (**Figure 25.7.**)

Where belt clamps are utilized, they must be securely anchored to the structure. The belt clamps should be sized correctly for the application and should have gripping sides that will hold the belt properly.

When the clamp is butted against the structure to block belt motion, the adjusting screws on the clamp—that create the 'pinching' action that holds the belt—should be no more than 30 millimeters [≈1.18 in.] from the edge of the belt. Clamping farther away from the belt edges creates too much bending on the clamp bars and reduces the strength of the clamp and the whole belt-blocking apparatus.

Keep in mind that the belt may move in either direction based on the conditions present at the time. Consequently, the belt should be clamped on both sides of the work zone so it cannot move in either direction; these conditions can and do change as the work progresses.

Figure 25.7.

To prevent belt movement, the belt clamp should be secured to a structural member capable of restraining the expected forces.

Image courtesy of Flexco.

Figure 25.8.

It is preferable to secure the clamps to the conveyor structure rather than an idler frame.

Image courtesy of Flexco.

Never tie off the clamps to the structure at an angle as this will apply uneven stress to the belt and weaken the blocking action. It is best if the clamp is positioned 90 degrees to the belt's direction of travel. Usually, this is not possible since the structure is always wider than the belt. Minimize the angle between the belt and the structure, as the breaking force applied to the cable for a given load is greater when the angle is greater. By choosing a clamp as close as possible to the width of the structure, the angle can be minimized.

Although, when pulling (stringing) a belt onto a conveyor, it is very common to use one cable in the center; never connect only a single tension or pulling device (come-along) when blocking the belt for maintenance. Always use two come-alongs so that even force can be applied on both sides of the belt.

Belt clamps must be inspected and tested before attachment to ensure that they are able to withstand the belt tensions. They should be inspected prior to each use and periodically returned to the manufacturer for inspection and testing.

An Idler Frame is Not Enough

Belt clamps should be firmly installed to or against the conveyor structure, rather than just rolling components such as idlers. (**Figure 25.8.**)

The use of idlers for the purpose of securing the belt clamps to block belt motion is not recommended, as the idler frame is designed for the loads of a short section of conveyor and has little strength to resist the stored energy. The forces of the belt tension—resulting from forces of the cargo and the pull of the takeup mechanism—can be significant and sufficient to pull the belt free from the relatively insubstantial construction of an idler frame.

It is much better to attach and secure belt clamps to the conveyor structure. This is typically a structural member of the framework engineered to withstand the types of load that the weight of the belt and cargo and tension of the conveyor system will produce.

Engineered Clamps for Safety's Sake

To securely attach a clamp to the belt to prevent movement, it is recommended that engineered equipment be used. The use of homemade devices composed of c-clamps, lumber, and chains can lead to problems and potential dangers. Homemade devices most likely will not be sufficiently strong enough to accomplish the job of controlling the stored energy, because they do not have the engineering design and testing to assure safety.

On the other hand, engineered belt clamps are specially designed to properly secure a belt to allow safe belt conveyor maintenance. Use the engineered systems within the limits of their design capacities to achieve safe and effective performance.

Engineered belt clamps are readily available from several suppliers, including the manufacturers of mechanical belt splices. (**Figure 25.9.**)

Checking for Risks of Movement

A pre-job analysis should be performed prior to assigning employees to work around belt conveyors. This should determine if a blockout procedure is required.

This pre-job analysis should include these questions:

A. Will any work be performed in pinch-point areas?

This includes all pulleys, carrying rolls, return rolls, drive components, and belt cleaners, as well as the sealing systems along the load zone.

B. Will the belt need to be cut?

The weight of the belt alone can make the belt travel forward or backward.

C. Will several crews be working on the conveyor system at the same time?

If so, will the work performed by one crew affect the safety of another crew working someplace else along or around the belt?

D. Is suitable blocking equipment available?

Clamps should be inspected before each use for defects and missing components. Damaged clamps or clamps with missing components should not be used.

E. Are workers trained in the proper application of belt-motion blocking equipment?

Companies should conduct regular training for those employees who work on or around belt conveyors.

Once it is determined there is a risk of belt movement, a blockout procedure should be applied.

BEST PRACTICES

Belt blockout should be used in conjunction with Lockout / Tagout procedures; it is not intended as a replacement for those procedures.

- Effectively blocking a belt should be done to prevent belt movement in either direction.
- Use only engineered belt clamps within their rated capacity.

Best practices when blocking a belt using belt clamps and come-alongs include:

Figure 25.9.

Engineered belt clamps useful for blocking belt motion are available from several manufacturers.

Image courtesy of Flexco.

- Move the section of the belt to be repaired to the lowest tension area of the conveyor if possible.
- Unload material from the belt and raise or release takeup tension.
- Try starting the conveyor from all operator and control room locations capable of starting the conveyor once the conveyor is locked out, tagged out, and blocked out. This is called Testout. (**See Chapter 24 Working Safely Around the Conveyor.**)
- When possible, move the belt to a work area where the tension is typically the lowest. On inclined belts, this is usually around the tail and on declined belts, the discharge.
- Inspect belt clamps before every use for defects and missing components. Damaged clamps or clamps with missing components should not be used.
- Be aware of the consequences if the come-along or clamp fails. The operator should never stand in line with the pulling force of the come-along.
- Mark the belting against a reference point to check for belt slippage.
- Stop pulling if slipping or belt creep is observed in the attachment of the clamp to the belting or to the structure.
- Release the tension when work is complete. It is recommended to release the tension on both come-along chains before loosening the clamping system.
- Contact the clamp manufacturer whenever in doubt about the application or clamp capacity required.

Figure 25.10.

If employees are required to be on the belt or near conveyor pinch points, the belt should be physically restrained from moving under its own stored energy.

Image courtesy of Flexco.

CLOSING THOUGHTS
Blocking Against Unwanted Motion

Even though a belt conveyor is locked out and tagged out, the risk of injury around belt conveyors remains high due to the chance for uncontrolled belt movement. If employees are required to be on the belt or near pinch points on the conveyor, the belt should be physically restrained from moving under its own stored energy. (**Figure 25.10.**)

A program requiring mechanical restraint of the belt using equipment engineered for that purpose and connected to the conveyor structure will protect employees who are required to work on or around belt conveyors. ⚠

3

Chapter 26 Conveyor Safety Training

INTRODUCTION

Training as a Way to Improve Safety

In the hierarchy of hazard mitigation effectiveness, training is a middle-of-the-road strategy being somewhat effective in reducing safety incidents and accidents. Despite the so-so effectiveness, safety training is a fundamental of any safety program. A facility simply must do safety training in order to have an effective overall safety program.

A report from the Bureau of Labor Statistics in the United States indicates mining companies spend about 40 percent of their total training hours on safety. The only industry that spends more of their training time on safety is the construction industry. To be effective and to produce a return on investment, training must be frequent and repetitive.

The Need for Training About Conveyors

Training—education of personnel on the functions of plant equipment and the proper procedures with which to operate and maintain that equipment—is a key ingredient in reducing accidents and improving performance of both personnel and the overall plant. It is, therefore, important to plant safety to provide training on belt conveyors. It is critical that employees be educated about conveyor operation and the potential hazards prior to being assigned to work on or around these high-powered, fast-moving, multiple-hazard systems. (**Figure 26.1.**)

One of the purposes of any training program is to make people aware of potential hazards before they are exposed to them. Many times, it is the newest hire—the least experienced employee—who is assigned the task of cleaning up or performing other simple maintenance chores around belt conveyors, with little or no knowledge or training on the dangers the conveyor may present.

Conveyors are complex systems where changes to one part of the system or to a component often have unintended consequences for production and safety. While most maintenance personal are mechanically or electrically inclined, they rely on intuition for making changes to a conveyor; this often results in making a problem worse. Maintenance workers are often under time pressure to get the system back on line, and the result is often treating symptoms and not correcting root causes. The lack of conveyor systems training is probably the biggest missed training opportunity for a company in finding and correcting root causes and predicting the effects on the system.

It is beneficial to an operation that its workers understand how the conveyors work—indeed, how all equipment works. Those workers will know when the system is running up to specification and conversely know when it is struggling. They will understand when a system is not performing at peak efficiency or heading for failure—a failure that might be devastating for production or profitability, or worse, catastrophic and tragic from a safety standpoint.

Training Requirements in the USA

In the United States, Mine Safety and Health Administration (MSHA) regulations in *Code of Federal Regulations (CFR) Title 30 Part 46* (for surface mines) and *Part 48* (for underground mines) require 24 hours of training for new hires. MSHA requires that four hours of that training be conducted before the new hire starts work, while the remaining 20 hours of training must occur within the first 60 days on the job. MSHA also requires documented training when a miner is assigned a new work task or transfers to a different facility. Lastly, every miner is required to participate in eight hours of refreshment training annually.

Task training must be given to all new and reassigned employees to instruct them in the proper way to perform their new job and to make them aware of the hazards associated with it. Hazard training should be given to all mine visitors to make them aware of any potential hazards within an area of work or travel on the property. (**Figure 26.2.**)

Typical topics in MSHA's eight-hour annual refresher training include:

- The Mine Act, Miner Act and Miner's Rights.
- Accident Prevention.

Figure 26.1.

Employees should be educated on how belt conveyors work, and how to work safely around them.

- Personal Protection Equipment (PPE).
- Personal Fall Protection Systems.
- Explosive Safety.
- Emergency Response (First Aid).
- Electrical Safety.
- Right-to-Know/Hazardous Materials Communication.
- Lockout/Tagout.
- Hearing Conservation.
- Site-Specific Training.
- Machine Guarding.
- Ground Control.

The regulations further require that the mines have a written training plan and keep records of the execution of the training program.

However, MSHA's requirements cover safety training for the entire mine operation and are not specific to conveyor belt operation and maintenance. Individuals working with or around conveyor belts would participate in the 24 hours of training required by MSHA, and then have task training for their specific job.

Employers not covered by MSHA—that are not mines or the associated processing plants—are not subject to the Parts 46/48 training requirements. So the training is left mostly unregulated and at the discretion of the hiring company.

In the United States, if a facility is not covered by MSHA, it falls under the Occupational Safety and Health Administration (OSHA). As such, each facility is responsible for safety training regarding pieces of industrial equipment—such as belt conveyors—used in that facility. As noted in the OSHA publication *Training Requirements in OSHA Standards, (OSHA 2254-07R 2015)*:

> OSHA's mission is to ensure the protection of workers and prevent work-related injuries, illnesses, and deaths by setting and enforcing standards, and by providing training, outreach, education and assistance. Many OSHA standards, which have prevented countless workplace tragedies, include explicit safety and health training requirements to ensure that workers have the required skills and knowledge to safely do their work. These requirements reflect OSHA's belief that training is an essential part of every employer's safety and health program for protecting workers from injuries and illnesses.

Many OSHA standards explicitly require employers to train employees in the safety and health aspects of their jobs. Other OSHA standards make it the employer's responsibility to limit certain job assignments to employees who are 'certified,' 'competent,' or 'qualified.'

Many companies have their own way of emphasizing the importance of safety by having regular, periodic—often weekly or even daily—safety meetings. These meetings should cover any new site-specific hazards. These safety meetings can often consist of talking about near misses and prevention, whenever the safety staff thinks these topics are particularly relevant.

Some 'tailgate talks' or 'toolbox talks'—the common names given to the daily or weekly safety reminder presentations given to a jobsite crew before work—include very basic information on belt conveyor safety. This information is generally along the lines of 'thou shall not' instructions. But unfortunately, these training sessions do not often include —and certainly do not emphasize—conveyors as a potential hazard. They also do not include the specific

Figure 26.2.

Hazard training should be provided for both mine workers and visitors.

3

task training for the jobs that must be performed on or around the belt conveyors.

Even the governmental agencies and commercial organizations that offer suggested topics or outlines for these brief, usually single-topic, talks note the brief talks are not intended to replace required more formal safety training.

Training Requirements in Other Countries

Every country—and likely every employer—may have specific (but different) requirements for training prior to putting new hires into the field where they can affect the productivity of the operation and the safety of themselves and of other workers.

In other countries around the world, little discussion in regulations and standards is given to conveyor-related operations, maintenance, and safety training. The Indian standard is more specific than most. In paragraph 3.3.15 of *IS 7155.2. (1986): Code of recommended practice for conveyor safety, Part 2*, the standard specifies:

> Suitable training (with particular reference to the operating and maintenance booklets) shall be given to continuous mechanical handling equipment personnel, both operating and carry out maintenance, as in the long run this may serve as the best form of accident prevention.

The conveyor safety guidebook from Canada's Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST), *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*, specifies in section 6:

> All operators and maintenance workers, who work on or in proximity to conveyors, must be informed of the hazards they may encounter, and receive training in established preventative measures and work procedures. All safety-related procedures and instructions must be documented.

Section 6.1 notes: "Only trained and authorized persons must be allowed to start up, operate and interrupt the normal operation of a conveyor." It then notes that operators should be instructed in duties including:

- Conveyor start-up
- Normal shut-down and emergency stop devices
- Required checks before starting up a conveyor after an emergency shut-down or accidental stoppage
- Proper loading procedures to avoid conveyor overload

Section 6.2 Maintenance Crew Training specifies that "only knowledgeable and trained workers possessing the necessary technical expertise to maintain conveyors" should be assigned to these duties. Among other instructions, the crew must be trained in lockout procedures, as well as in procedures for installing or reposition guards.

Site-Specific Training

Site-specific training—that is, training in the operations and equipment employed at a particular work site—is required by most countries. Site-specific training is designed for visitors who are on site for a limited period of time. MSHA regulations note in *CFR 30 Part 46* section 46.2.(2):

> The definition of 'miner' does not include scientific workers; delivery workers; customers ... ; vendors; or visitors. This definition also does not include maintenance or service workers who do not work at a mine site for frequent or extended periods.

While not considered technically a 'miner' by definition, if workers inspect, maintain, and/or service mining equipment at mine sites for frequent or extended periods, they are engaged in "mining operations" under Part 46, and are considered miners for training purposes. However, if these employees are not at mine sites for frequent or extended periods, they will not be considered miners for training purposes and must receive site-specific hazard awareness training at each mine. (**Figure 26.3.**)

'Frequent' exposure is defined as a pattern of exposure to hazards at mining operations occurring intermittently and repeatedly over time. 'Extended' exposure means exposure to hazards at mining operations of more than five consecutive work days.

The effectiveness of site-specific training depends upon the comprehension and retention of the material. Most facilities require site-specific training be updated (repeated) once a year. Unfortunately, site-specific training is often considered just another paperwork task required to satisfy a bureaucratic requirement.

Considerations for site-specific training include:

- If the site-specific safety rules can be made simple and universal they are more likely to be remembered and followed.
- Training should focus on informing about the hazards where accidents are most probable and have the highest consequences.
- Site-specific training will be more effective if the trainee is required to answer questions, either on a form or online rather than merely 'checking the box' and sign without closely reading or watching.
- Site-specific training materials should be kept up to date.

Figure 26.3.

Site-specific training provides instruction on the particular hazards of each facility.

CEMA offers DVD for Belt Conveyor Safety Training

The Conveyor Equipment Manufacturers Association—commonly known as CEMA—has released a belt conveyor safety training video suitable for training end users (operators), as well as conveyor manufacturers and distributors.

Produced in English, the 13-minute DVD provides 12 safety rules and lessons for safer operation and maintenance of belt conveyors used in the handling of bulk materials. These lessons are tied to the other materials available from CEMA as free downloads, including:

- CEMA Bulk Conveyor Safety Poster
- Conveyor Safety Label Placement Guidelines
- Conveyor Accessory Safety Label Placement Guidelines

The *Bulk Handling Conveyor Safety Video* DVD, much of which was filmed in Martin Engineering's conveyor laboratory, was released in 2010. Cost for the DVD is $20 (USD).

The belt conveyor video joins CEMA's family of safety training videos, which also includes *Unit Handling Conveyor Safety* DVD and *Screw Conveyor, Drag Conveyor and Bucket Elevator Safety* DVD. To order or for more information, visit *http://www.cemanet.org/cema-safety-videos.*

In addition to its safety videos, CEMA also offers other conveyor safety materials including conveyor safety labels, label-placement guidelines, posters, a technical report on noise-hazard reduction, and tips on the design and safe application of conveyor crossovers. For information, visit the CEMA website at *www.cemanet.org*.

Bulk Handling Conveyor Safety Video DVD
http://www.cemastore.com/shop/item.aspx?itemid=94

Conveyor Training as Adult Education

Industrial training is often seen as repetitive and less than exciting. Consequently, employee attendees are passive and non-responsive. The workers do not ask questions and may not respond to questions or prompts from the instructor. There is little interaction; student involvement consists of answering an occasional question or taking a quiz of some nature. Current methods of using videos and slide-show presentations are passive in nature with no first-person interaction and no prescribed method of assessing the retention of knowledge gained.

Review of the educational studies indicates there are better ways to help adults learn and—most importantly—retain the information from training events and thus improve their safety awareness.

Robert W. Pike, an internationally recognized expert in human resources development, noted some principles of adult learning in his book, *Creative Training Techniques*. The following are attributed to Pike, but were found in the article, *The Bar Has Been Raised (Part 2)*, by Joseph P. McGuire and Billy Snead:

- Adults bring a wealth of experience that must be acknowledged and respected in the training setting.
- Adult learning is enhanced by hands-on experience that involves adults in the learning process.

The article continues, "Adult learning is improved when 'hands-on' and life experiences are incorporated into training sessions." Instructors should generate interaction that encourages the learners "to come up with ideas, questions, suggestions and solutions to problems or issues." This "will be more effective than giving them facts, rules, and other information to remember." (**See Pike's Laws of Adult Learning.**)

It is essential to learning and retention to get learners to apply information quickly in the real world. That way, the workers quickly make the connection between illustrations and photos in a PowerPoint presentation, and the

Pike's Laws of Adult Learning

As found in Chapter 3, "Ultimate Adult Learning," in the book *The Ultimate Educator* from the National Victim Assistance Academy, Robert W. Pike's 'laws' for industrial trainers are interpreted and summarized below.

Law 1: Adults are babies with big bodies.

It is accepted that babies enjoy learning through experience, because every exploration is a new experience. As children grow, educators traditionally reduce the amount of learning through experience to the point that few courses in secondary and higher education devote significant time to experiential education. It is now recognized that adult learning is enhanced by hands-on experience that involves adults in the learning process. In addition, adults bring a wealth of experience that must be acknowledged and respected in the training setting.

Law 2: People do not argue with their own data.

Succinctly put, people are more likely to believe something fervently if they arrive at the idea themselves. Thus, when training adults, presenting structured activities that generate the students' ideas, concepts, or techniques will facilitate learning more effectively than simply giving adults information to remember.

Law 3: Learning is directly proportional to the amount of fun you are having.

Humor is an important tool for coping with stress and anxiety, and can be effective in promoting a comfortable learning environment. If you are involved in the learning process and understand how it will enable you to do your job or other chosen task better, you can experience the sheer joy of learning.

Law 4: Learning has not taken place until behavior has changed.

It is not *what you know*, but *what you do* that counts. The ability to apply new material is a good measure of whether learning has taken place. Experiences that provide an opportunity for successfully practicing a new skill will increase the likelihood of retention and on-the-job application.

specific conveyors and conditions they will see in real life, at their place of employment.

Suffice it to say that in most (if not all) cases, adult learning is better with hands-on, self-directed information that is directly applicable to the opportunities and challenges in the immediate environment. That is why conveyor training is more effective if the training includes hands-on activities and specific references to conveyors in that plant.

Evaluating the Impact of Training Programs

The evaluation of training programs—such as a conveyor safety training—is critical to the learners, to make sure they are getting what they need to work safely and effectively, and to the operation, to make sure that the plant is getting its money's worth from its investment in the training program.

One of the most accepted methods for evaluating the effect and value of training is what has been termed the Kirkpatrick model. First proposed by Donald Kirkpatrick in 1954 as a University of Wisconsin graduate student, this model serves as an excellent planning, evaluating, and troubling-shooting tool to judge the success of any training program. Kirkpatrick's model became widely known after it was published in 1994 in his book, *Evaluating Training Programs: The Four Levels.*

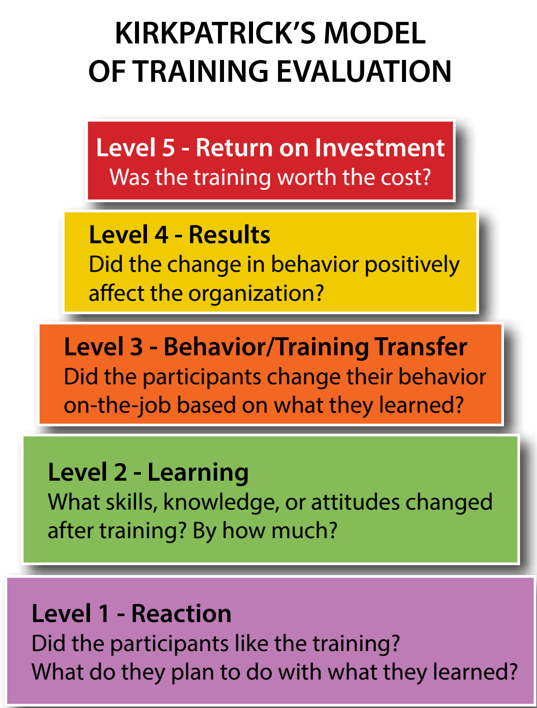


Figure 26.4.

The Kirkpatrick Model for training evaluation was developed by Donald Kirkpatrick and later modified by others.

The Kirkpatrick model has four steps or levels by which to evaluate a training program. (**Figure 26.4.**) These steps are summed up in a PowerPoint presentation, *Patient Safety Training Evaluations: Reflections on Level 4 and more*, by Eduardo Salas, Ph.D., as follows:

- **Level 1: Reaction**
  Did the learners like the learning program? *(Were they engaged?)*
- **Level 2: Learning**
  Did the learners gain knowledge and skills? *(Was the training educational?)*
- **Level 3: Behavior**
  Did the learners apply the learning to their job performance and change their behavior? *(Do they have the capability to perform the newly applied skills on the job? Are they empowered to make change?)*
- **Level 4: Results**
  Did the application of the learning program affect company results? *(Has the company benefitted from tangible results, in terms of reduced cost, improved quality, improved safety, increased production, or heightened efficiency?)*

To summarize the Kirkpatrick model, in order to provide a tangible benefit for the operation, any training needs to be enjoyable, educational, behavior-changing, and accepted and reinforced by management.

Some training theorists have subsequently added a fifth level to the Kirkpatrick evaluation model:

- Level 5: Return on Investment
  Was the training worth the cost? *(Did the improved performance provide a payback on the expense incurred for the program?)*

Unlike other forms of task and job-related training, the return on investment for safety training is not easy to measure. (**See Chapter 34 The Payback for Safety.**)

Conveyor Safety Training: The Present State

Currently, industrial training to work safely around belt conveyors is the responsibility of the owner/operator of the facility. In the United States, both the Occupational Safety and Health Administration (OSHA) and the American National Standards Institute (ANSI) classify conveyor belt safety into the general operational and safety training. Both organizations place the responsibility on the owner to use a certified, qualified, and competent person to train the operators.

There has been little in the way of conveyor safety training materials offered in ANSI Conveyor Safety Standards, OSHA, or any of the safety engineering professional associations. As noted by George Schultz in "Training for Conveyor Safety" in 2003 (and cited by Poonam Worlikar in a master's thesis), these associations have some general safety guidelines, but do not place training requirements nor suggest a training program structure or specific training guidelines. This leaves the responsibility of developing a successful training program to the owner/operator of belt conveyor. Worlikar's thesis continued:

> With the lack of developed training programs, conveyor belt training is left to on the job training where a new employee is placed with experienced personnel to learn the workings of the conveyor belt and proper operations and maintenance. The one downfall for on the job training is that as the training cannot be quantified and checked to make sure that the training period is adequate, it also allows for a chance of injury because inexperienced personnel are exposed to the dangers of a conveyor belt system.

The common practices of training about belt conveyors within the industry are to incorporate brief basic safety considerations and tips into videos and slide shows that are presented as part of the general safety training.

Conveyor training programs that include safety are available from Martin Engineering (**See Conveyor Training at Ste. Genevieve Mixes Classroom with 'Real World.'**) and several other suppliers; these presentations are often built around classroom training presentations (**Figure 26.5.**) but may offer additional field or hands-on exercises as an option.

Content for Conveyor Training

In order to help reduce accidents with a comprehensive safety training program, it is important to include certain areas of training. The content areas for a conveyor safety training program should include the following as goals:

The learner should understand (be able to recognize and articulate):

- The various types of hazards presented by conveyor systems and the safe work practices for preventing these hazards from causing injury.
- The importance of avoiding both intentional and unintentional contact with conveyors.
- The requirements and skills of a qualified conveyor operator.
- The significance of Lockout / Tagout procedures during conveyor maintenance and repair.
- The unintended effects of making changes on conveyor system components.

Figure 26.5.

Classroom presentations are often a part of conveyor training.

3

Conveyor Training at Ste. Genevieve Mixes Classroom with 'Real World'

In 2009, Holcim (US) opened its Ste. Genevieve cement plant on the Mississippi River in Missouri. With a production capacity of four million tons per year, the Ste. Genevieve plant is the largest single-kiln Portland cement plant in the world. Now part of LafargeHolcim, the state-of-the-art plant with approximately 250 employees is one of the most environmentally efficient and safest in the world.

In early 2014, with an eye to improve safety, control fugitive material, and increase overall plant performance, the Ste. Genevieve facility undertook a program to improve employee knowledge about safety and performance enhancement of its belt conveyor systems.

"Belt conveyors are the single most dynamic and potentially dangerous areas of equipment on a plant site," said Jim Wrigley, Training Manager for the Ste. Genevieve plant. "The safety and improved performance of conveyors are critical to the plant's success."

The Knowledge Gap about Belt Conveyors

Jerad Heitzler, who leads Martin's conveyor training efforts in the United States, explains:

> Plant personnel are focused on the production of their operation's main product—cement. The 'care and feeding' of belt conveyors, that is, the adjustment, maintenance, and troubleshooting that often make the difference in performance and profitability, are just not in the expertise of plant personnel. It is not that the workers do not care about conveyors, but the care of these systems is often outside their focus and their time constraints.

To help plant personnel understand their operation's own conveyors, see what their conveyor problems are, and what the potentials can be, Martin Engineering provides worker training on belt conveyor systems. These programs focus on projects that can improve safety for those who work on or around belt conveyors, and conveyor renovations that can reduce the need to work on or around belt conveyors. For more than 20 years, Martin has offered one- and two-day workshops on operating and maintaining clean and safe belt conveyors to operating plants across the industry and around the world. The courses are called the *FOUNDATIONS™ Workshop* and covers the basics of belt conveyor operations and maintenance and the principles of the control of fugitive material.

"Part of this is just learning to see belt conveyors in a new way, knowing what to look for, and knowing a problem when you see it," says Heitzler.

The *FOUNDATIONS™ Workshop* was developed by Martin Engineering as a way to help plant personnel understand the operation and maintenance of the material-handling systems on which their facilities depend. Offered as a one- or two-day session of classroom instruction, and now available in an online, e-learning course, the workshop covers belt conveyors used for handling bulk materials.

Heitzler continues:

> The goal is to instruct plant personnel—operators and managers alike—on the principles of conveyor operation, and the signs of, and the corrections for, a number of common conveyor problems—like mistracking, fugitive material, damaged components, and other common hazards. The workshop teaches plant personnel what to expect from their belt conveyors. It also talks about how to get more—that is, greater safety, more dust control, more efficiency, and more productivity; and how to get less—fewer hazards, less fugitive material, less belt wander, less maintenance headaches, and reduced conveyor problems.

Getting the Message

Together, Martin Engineering and Ste. Genevieve management developed a plan. In a week of training, Martin would provide two identical two-day courses. Attending the sessions were Ste. Genevieve plant operators (cement technicians) as well as the technician coordinator and two plant reliability engineers.

The employees were divided into two groups, with Group A—26 employees—receiving classroom instruction on Monday and Tuesday, and Group B—16 workers—going through the training program on Wednesday and Thursday. Friday was reserved for follow-up discussions between those who received the training and plant managers.

Contents of the Course

Material covered in the classroom portion of the *FOUNDATIONS™ Workshop* taught at the Ste. Genevieve plant included:

- *Construction of the Conveyor*: Basics of the structure; Identification and function of the various components.
- *Conveyor Safety*: Safety when working on or around belt conveyors; Safety systems on belt conveyors.
- *Conveyor Belting*: Construction, condition, and types of damage; Mechanical and vulcanized splices.
- *Belt Tracking*: Causes of belt wander; Methods of correcting the belt path.

- *Transfer Points*: Transition distances; Loading zones; Impact areas; Importance of belt line stability; Effective side sealing.
- *Discharge Zone*: Characteristics of carryback; Belt cleaning systems.
- *Dust Management*: Air movement in transfer points; Dust containment; Active and passive dust collection; Dust suppression systems.
- *Return on Investment*: Calculating the ROI on conveyor improvements.

An important precursor of many *FOUNDATIONS™ Workshops* is an inspection of the conveyors in the facility the day before the course. This allows the training to incorporate information about the local materials-handling system and its 'real world' problems into the training materials. Digital photographs taken during that site visit bring home to participants the real nature of their plant's conveyor problems and spur discussions of causes and possible solutions.

Site Survey Incorporates 'Real World' Information

At Ste. Genevieve, special field experiences were built into the course content. On the first day of each group's training, an afternoon 'walk down' of one plant conveyor presented a basic review of typical issues that the cement technicians might encounter. Small teams from the class inspected one of the conveyors in the Ste. Genevieve facility, checking for problems and creating a site survey. This survey would report on the condition of structure, belting, tracking, idler, pulleys, loading-zone seals, belt-cleaning systems, and other conveyor components.

On the afternoon of the second day of each group's training sequence, participants were given an assignment. Each team was to propose the solutions—in terms of adjustments, corrections, and new equipment—to improve the safety and performance of the conveyor the group had inspected the day before. The notes and photos from the previous day's site survey were assembled in a 'condition report' that was presented to the other teams and management in a 'Report Out' session at the conclusion of the week of training.

On the morning of the final day of the training sequence, representatives of each group's participants gathered for a summary discussion. After a review and discussion of their observations, each team prepared a report to present to plant management. The reports included a recommendation of improvement projects based on what they had learned in the classes that should be completed on their conveyor. Each recommendation included a budgetary quote using 'ballpark' cost estimates provided by Martin Engineering.

Evaluating the Training

Any training program should be evaluated twice, by both the individuals undergoing the training and by the plant or corporation sponsoring the training, to see if the program fulfilled expectations as far as enabling and motivating personnel to improve plant operations. Course attendees and the Ste. Genevieve plant management were pleased with the success of the program—with both the information covered in class and the site survey reports produced by the attendees.

For Holcim, a key for evaluating the success of the conveyor training program was its fulfilling of the four steps of the Kirkpatrick evaluation model. (**See Evaluating the Impact of Training Programs.**) The proof of the success of the *FOUNDATIONS™ Conveyor Training* would be if the learners would be able to apply the information to the specific conveyors and materials-handling issues of the Ste. Genevieve Cement Plant.

Jim Wrigley, Training Manager for the Ste. Genevieve plant, explained:

> We consciously designed this training to apply to 'real world' conditions. We asked our personnel to walk the conveyors in their areas of responsibility and then to assess the equipment and its performance. They then brought back that information to share with their peers and plant leadership. Some of the proposed changes have now been implemented; others are in the budget approval process. This way, we have taken the right steps to demonstrate that our people learned from the training program and can apply it to their jobs. Time will tell if we can show the results that will provide the long-term benefit to the operation and company, but we are confident that we have taken the right steps.

A Pilot Program

Similar training programs can be utilized at other cement manufacturers as well as at other operations where the handling of bulk materials on belt conveyors is critical to a plant's operational, financial, and safety success.

The instruction program can be very similar for other facilities and other industries, adds Heitzler:

> But the key will be to customize the training program and instructional materials to match the specific equipment, conditions, and requirements of those plants, whether they are engaged in cement manufacturing or other forms of bulk-materials handling.

In describing a general conveyor training program in *Aggregates Manager* magazine in 2003, an article titled "Conveyor Safety and Education" by Larry Goldbeck proposed four areas of conveyor training: general safety practices, guidance for performing conveyor maintenance and inspection procedures, information about belt and conveyor system conditions, and procedures for aligning components so the belt runs in the center.

General safety practices include using the proper personal protective equipment and making sure each employee is aware of emergency-stop button or cord locations.

Guidance for performing maintenance and inspections includes making sure the conveyor is properly locked out and tagged out when performing maintenance tasks, performing the tasks properly, and making sure any connected equipment is properly placed out of service with the power locked out and the belt blocked against movement.

The training also needs to include general conveyor system conditions, such as how to make sure idlers are properly working and the ability to recognize the sources and causes of fugitive material. The employee also needs to be trained on belt conditions and be able to recognize various types of damage to belts and splices.

The training of the belt—sometimes called tracking the belt—is the art and science of manipulating conveyor belt components to get the belt to run in the center of the structure. The adjustment of these components to align the belt while it is in operation can lead to serious injury and costly belt damage. Consequently, the training of the belt is an important subject for the conveyor training course.

Figure 26.6.

Training should include information on the construction, operation, and hazards of belt conveyors, as well as instructions on the safe performance of the tasks that will need to be performed.

This instructional content comprises the general information about conveyors—construction, operation, and hazards. In addition, the training should include instructions on the safe performance of the specific operations and maintenance tasks that will need to be performed. (**Figure 26.6.**)

Task Training for Conveyor Work

Task training, that is, training in the performance of the specific jobs and maintenance chores required around the belt conveyor system, can be one of the most effective means of accident prevention.

No matter the specific characteristics of the conveyor or the plant process, four categories of conveyor-related tasks can be easily identified; they are:

Cleaning
The cleaning around and under the belt and equipment to remove spilled debris accumulated on belt components or built up on the floor under the belt. Cleaning is frequently done using hand tools.

Installation and Repair
The installation and service of conveyor components and structure.

Belt Alignment
The adjustment of conveyor components so the belt will track in the center of the structure.

Other
This includes miscellaneous tasks such as inspection, maintenance of large equipment (such as loading systems) near the belt, and service of other conveyor-related systems, such as material samplers, tramp iron magnets, bin-level detectors and flow meters, and safety switches.

Any task training should include familiarization with the work area, potential safety hazards associated with the job, a review of safe working procedures for the equipment to be used and the job to be done, and a review of

3

company and governmental safety regulations pertaining to the job.

Even with effective task training, the initial work for the new employee—or even a veteran employee with a new assignment—should also be closely supervised until all are confident the worker has the ability to perform the job safely.

As noted earlier in this book, the performance of maintenance and cleanup around belt conveyors is a leading cause of conveyor-related accidents and injuries. With proper task training, these injury rates can be abated.

Studies show that for critical maintenance procedures, simulations or practicing on a duplicate piece of equipment are very effective methods of developing safer ways to perform tasks.

High-Tech Conveyor Safety Training

Current and conventional safety training practices generally include the use of lectures, slide-show presentations, videos, and paper materials. In some cases, the training continues by sending each trainee onto the site with an experienced worker for on-the-job task training.

Unfortunately, these education methods are passive in nature; that is, the learner is a vessel into which the knowledge is poured, rather than an active participant. Research in adult learning methods have indicated that active learning/training is more effective than the more passive learning/training methods.

Accordingly, the use of interactive multi-media is becoming more prevalent in many training programs due to its effectiveness and cost efficiency. Reasons cited as to why use of multi-media is gaining popularity among the training programs include reduced costs, savings in time, interactivity of material, immediate feedback, consistency in the presentation of the information, and flexible delivery.

This high tech training methodology can take several forms, including online training courses, simulators, and virtual reality technologies.

Simulators for Training

Some mining operations use computer-based simulators to train employees on the operation of the heavy equipment used in that facility—mining shovels, haul trucks, drill rigs, and the like.

Similar to cockpit simulators used in aviation training, these mining equipment simulators replicate the driver compartment controls and

3

Advanced Seminar Offers Higher-Level Training

Well-designed, well-managed conveyor systems provide cleaner, safer, and more productive bulk-materials handling. To achieve those goals, Martin Engineering's *Foundations™ Advanced Seminar* will assist plants with designing, operating, and managing belt conveyors and in justifying improvements in conveyor systems.

Growing out of the 4th edition of Martin Engineering's book *Foundations™, The Practical Resource for Cleaner, Safer, More Productive Dust & Material Control*, the Advanced Seminar was developed for engineers and managers responsible for the design and administration of belt conveyor systems.

Typically, the first day is on designing cleaner, safer, and more productive conveyors. The second day is based on this book and focused on the return on investments in safety.

The course is focused on the improvement of conveyor systems to reduce fugitive material, control dust, extend component life, increase safety, and improve performance. It provides information on how to improve belt conveyor systems, and how to demonstrate these improvements in order to justify the investments required. It covers methods for the calculation of the cost and the benefits of those improvements.

the view as seen from the driver's seat. They are designed with realistic movements, graphics, and machine response, which allow the practice of operator skills without risking lives or valuable equipment.

Simulators bridge the gap between classroom, lecture-style training and live, hands-on equipment training. As the article "Training: The Foundation for Safety" published in the February 2014 edition of *Engineering and Mining Journal (E&MJ)* pointed out, through these simulators, operators can be exposed:

> ... not only to normal operating conditions, but also to abnormal and emergency scenarios in complete safety. By practicing rare events in the simulator, the best response can be taught and becomes second-nature if the scenario ever occurs in real life.

There have been no simulators developed for conveyors yet, but initial attempts at the use of virtual reality in conveyor training seem to be moving in that direction.

3

Training in Virtual Reality

Another high tech method of training is the use of computer-based virtual reality (VR). Virtual reality is a computer-based environment that simulates a physical presence in places in a real or imagined world. Virtual reality offers a realistic first-person experience where users can go through the training at their own pace, experience actions and their consequences, and have their performance tracked. These systems would allow workers to experience the conditions without actually risking injury or restricting the operating equipment and production schedule.

As summarized in the 2007 paper, *A VR-Based Training Program for Conveyor Belt Safety*, by Jason Lucas, Walid Thabet, and Poonam Worlikar:

> Virtual reality (VR) provides the opportunity to develop interactive virtual training applications that are comparable to real life simulations but could be more cost effective. Interactive VR applications designed for safety training can provide better cognitive learning tools by allowing trainees to actively participate and experience in near-reality sense the hazards associated with working around conveyor belts and to virtually practice performing tasks without the dangers of a working belt.

Bluefield State College Explores Online Conveyor Safety Training

The Center for Applied Research and Technology (CART), Inc. at Bluefield State College (BSC) has recently developed online materials to complete a web-enabled course of instruction to improve conveyor belt safety training.

The program was developed under the sponsorship of a grant from the United States Department of Labor as part of a program to provide education and training within the mining industry. The grant was one of six awarded in 2010 through MSHA's Brookwood-Sago grants program, which was established through the Mine Improvement and New Emergency Response (MINER) Act of 2006. The focus of all 2010 program grants was on training and training materials for mine emergency preparedness and prevention for all underground mines.

CART demonstrated its program and its results at the fifth annual BSC Mine Rescue Competition, the 118th annual American Society for Engineering Education (ASEE) Conference, and at the 2011 Bluefield Coal Show.

The trial course was well received by the approximately 90 mine safety trainers who participated in the demonstration, but a lack of additional funding led to a halt of development and distribution of the program.

VR offers the benefit of safely rehearsing activities and demonstrating consequences for mistakes that on-the-job, hands-on, 'real world' training does not allow.

For a demonstration program, Lucas, Thabet, and Worlikar developed a series of instructional-based and task-based VR modules to assist the user in understanding the components and assemblies of the conveyor belt. The modules explained the different hazards and safety issues associated with moving belt components when performing maintenance, and tested the user's ability to resolve problems.

The application of virtual reality training, if fully developed, can be part of the solution of effectively training a large number of younger miners—those who are more likely to be computer literate and familiar with the VR system's video game-like controls—in an interactive and safe environment.

While pleased with the initial results of the virtual reality training program, the researchers were conscientious to point out that even with the demonstration program, it was not anticipated that on-the job, hands-on 'real world' training can be eliminated. The use of VR should not replace this training but enhance it.

There have been initial and partial (graduate-school-project) attempts to develop VR conveyor training. (**See Virginia Tech Project Demonstrates Virtual Reality Conveyor Training.**) However, none has yet reached the marketplace in a finished state, ready to be adopted (or adapted) for training in specific facilities. Perhaps it is only a matter of time.

Outside Resources for Training and Safety

There are many companies and consultants that can provide predesigned or custom training programs. Many of the trainers for general safety instruction and consulting are certified safety professionals.

Safety professionals are persons certified by an accredited organization who spend at least 50 percent of their work time on safety duties, including making worksite assessments to determine risks, assessing potential hazards and controls, evaluating risks and hazard control measures, investigating incidents, maintaining and evaluating incident and loss records, and preparing emergency response plans. Other duties could include hazard recognition, fire protection, regulatory compliance, health hazard control, ergonomics, hazardous materials management, environmental protection, training, incident investigations, advising management, record keeping, emergency response, managing safety programs, product safety, and/or security. Many of the topic-specific instructors for specialized training are employed by manufacturers, and while not certified safety professionals, are subject matter experts.

Outside experts can often uncover safety issues that are not obvious to those working every day in a mining or industrial environment. It is common for bulk-materials-handling companies to utilize safety service companies for routine inspection of safety equipment—fire extinguishers, for example. Many safety service companies offer site inspections, safety culture evaluations and customized training programs.

3

Online Conveyor Training Offered by Martin Engineering

Internet-based training courses in conveyor operations, maintenance, and safety are available. Martin Engineering offers an online course on conveyor operations maintenance and safety. Based on Martin's *FOUNDATIONS™ Workshops*, the seven-module course covers the basics of conveyor construction, key factors for safety when working on and around belt conveyors, and methods to improve conveyor performance through the control of fugitive material. More information is available at *www.martin-eng.com/page/foundations-online-training* or contact Martin Engineering.

Virginia Tech Project Demonstrates Virtual Reality Conveyor Training

The success of virtual reality training in other fields has led to some initial preliminary research in applying VR to conveyors. In a Virginia Tech master's thesis titled *Improving Conveyor Belt Safety Training Through the Use of Virtual Reality*, Jason David Lucas developed a demonstration of virtual reality conveyor training.

The program was comprised of two interactive phases: an instructional-based phase and a task-based phase. In the introduction, Lucas explains:

> The instructional-based phase is a guided walk-through simulation intended to familiarize the trainee with the working environment around a conveyor belt, the conveyor belt components, and to alert the user of the maintenance tasks and related hazards of the moving components.
>
> The second phase of the study involves task-based training. Simulations of various problem scenarios will be developed to test the user's ability on resolving problems while immersed in the VR environment. Information related to the task can be accessed from within the simulation and the trainee's ability to identify and remedy risks can be quantified. Consequences of poor decision-making or risk-taking behaviors while interacting with the environment will be demonstrated to the user.

Sample Scenarios from VR Conveyor Training

The virtual environment in the master's thesis illustrated three different conveyor systems: an inclined conveyor, an elevated conveyor, and a conveyor at grade. This allowed for the inclusion of a variety of possible hazards including material spillage, performing maintenance at elevated heights, and being within close vicinity to the moving parts of a conveyor.

The training required the use of proper sequences for various conveyor-related tasks and operations. One example is the turning 'ON' of the belt system. The power breaker needs to be in the 'ON' position and unlocked before the power switch will work. The VR animation shows the process needed to turn on the conveyor system. If the belt is locked out, the trainee could not have the plant operator turn it on. Once the breaker was unlocked, the belt could be turned on. Once the system was 'ON,' the alarm would need to be sounded by the user before the belt could move.

Another example is in the hazard identification sequence. In one instance, a mound of material exists that might interfere with the proper running of the belt. The user is asked a series of questions about what the hazard is and how to remove it. When the user answers correctly, the hazard is removed from the scene. If the user answers incorrectly, the consequence of what would happen if the hazard is not removed, or removed improperly, is shown.

The project was part of a research program at Virginia Tech to investigate the effectiveness of VR for training of personnel working around conveyor belts in the surface mining industry. The program was funded by a grant from the National Institute for Occupational Safety and Health (NIOSH).

Slides from the demonstration project depict conveyors in virtual reality. (Images courtesy of Jason David Lucas.)

Most safety service companies will provide reports and offer proposals for hazard mitigation or remediation.

Selecting a Safety Service Provider

The use of a specialized contractor for safety-related activities can provide a benefit over using in-house maintenance personnel. In addition to a 'second set of eyes' on an operation, the expertise and experience of an independent service provides a valuable advantage. For example, in the United States and the European Union, the responsibility for risk analysis extends beyond the manufacturer who supplied the equipment. The equipment end user is also responsible for conducting and documenting risk analysis for equipment in the context of the operation. Formal risk analysis is not a skill often found in maintenance departments.

When selecting a contractor for making safety inspections or improvements, consider consultants with:

- Knowledge of the local and national safety regulations applicable to the mine or processing industry.
- Knowledge of belt conveyor design and operation.
- Experience and references.
- Superior safety records.

When selecting an outside service consultant, consider the potential savings rather than focusing solely on price.

BEST PRACTICES

The methods for safety training are very similar to other types of training required in mining and industry. To be effective, training must be frequent, but training need not be only formal classroom training to be effective. A mixture of classroom, field, and online training using both in-house and outside resources can make training more effective.

Generally speaking, the people being trained in safety around conveyors are maintenance and operating personnel who tend to be hands-on learners. The most effective training will probably be a combination of presentations and demonstrations while allowing and encouraging as much participation as possible. These same people tend to be action oriented and not used to spending prolonged periods sitting, reading, or watching presentations so keeping the training short and to the point is recommended.

The Best Practices listed below are drawn primarily from *EH&S Training Best Practices, Standards, and Guidelines*, as developed in 2011 by a Systemwide Training and Education Workgroup of the University of California.

These recommendations do not cover development of training materials.

Class Size

- A small class size encourages interaction. (**Figure 26.7.**) A class of 25 individuals (or fewer) typically works best, especially when incorporating activity-based learning into the training program.

Facilities

The 'learning space' should encourage small-group exercises or hands-on training using equipment as part of activity-based learning.

Figure 26.7.

Interaction between students and instructor and among students themselves, is typically enhanced by a small class size.

3

Organizations Offering Safety Training Resources

Several organizations provide safety resources including certification of safety professionals:

American Society of Safety Engineers

www.asse.org

The American Society of Safety Engineers (ASSE) is the world's oldest professional safety society. ASSE promotes the expertise, leadership, and commitment of its members, while providing them with professional development, advocacy, and standards development. It also sets the occupational safety, health, and environmental community's standards for excellence and ethics. ASSE has affiliates in many major mining countries.

Board of Certified Safety Professionals

www.bcsp.org

The Board of Certified Safety Professionals (BCSP) is not a member organization and does not provide services usually offered by member organizations. Membership in any organization is not a requirement for certification. BCSP's sole purpose is to certify practitioners in the safety profession.

National Association of Safety Professionals

www.naspweb.com

The National Association of Safety Professionals (NASP) is a non-profit membership organization providing training, consultative services, and third-party certifications that validate knowledge, skills, and abilities in the area of workplace safety. The primary mission of NASP is to provide safety professionals with innovative training opportunities and professional certification to assist them in carrying out their safety-related functions with confidence and proven competence.

International Board for Certification of Safety Managers

www.ibfcsm.org

The International Board for Certification of Safety Managers, also known as BCHCM, was established in 1976 as a not-for-profit independent credentialing organization. The Board establishes certification and re-certification requirements for the Certified Healthcare Safety Professional (CHSP). The Board operates as an independent professional credentialing organization that is not affiliated with any other membership group, association, or lobbying body.

Board of Canadian Registered Safety Professionals

www.bcrsp.ca

The Board of Canadian Registered Safety Professionals (formerly the Association for Canadian Registered Safety Professionals) is a public interest, not-for-profit association with a membership dedicated to the principles of health and safety as a profession in Canada. A Canadian Registered Safety Professional (CRSP®) is an individual who has met the requirements for registration established by the Governing Board. A CRSP® applies broad-based safety knowledge to develop systems that will achieve optimum control over hazards and exposures detrimental to people, equipment, material, and the environment. A CRSP® is dedicated to the principles of loss control, accident prevention, and environmental protection as demonstrated by their daily activities.

European Network Education and Training in Occupational Safety and Health

www.enetosh.net

The European Network Education and Training in Occupational Safety and Health (ENETOSH) offers a platform for systematic knowledge-sharing on issues concerning education and training in occupational safety and health. Today, more than 40 partners from 16 European countries plus South Korea are involved in ENETOSH. The network is coordinated by the Institute for Work and Health (IAG) of the German Social Accident Insurance (DGUV) Institute. The membership jointly developed the ENETOSH standard of competence for instructors and trainers in safety and health. The development was carried out on the basis of the European Qualification Framework (EQF). The standard covers four fields of competence:

1. Education and training
2. Safety and health at work
3. Workplace Health Promotion (WHP)
4. Occupational Safety and Health (OSH) management

The Safety Institute of Australia, Ltd.

https://sia.org.au

The Safety Institute of Australia conducts certification of the Generalist OHS Profession, through a program which acknowledges the capability and credibility of OHS Practitioners and Professionals though the combination of their education and work experience. Certification of Generalist OHS Professionals/Practitioners is not compulsory. Certification is not regulated under law, by the State OHS regulators, or any government body. Certification is a process which is being voluntarily implemented by the profession to contribute to the highest standard of health and safety advice available to Australian workplaces.

Adequate and appropriate facilities to support the training include the following:

- Space for attendees to sit comfortably and be able to see, hear, and participate in the presentation.
- The room should be quiet enough for normal conversation to be heard.
- Make sure all learning technology (projectors and sound systems) is operational and have technical support available.
- Controls for room lighting and temperature should be accessible by the trainer.
- Windows should have shades that block light to improve viewing of screen or video displays.

Instructors

- Instructors should be subject matter experts who can deliver content in a classroom setting.
- Some regulations (such as *29 CFR 1910.1210)* require trainers to have special qualifications.

Techniques

The best teaching methods:

- Draw on the participants' own knowledge and experience about health and safety issues.
- Emphasize learning through doing without relying on reading.
- Incorporate a variety of learning principles, methods, and activities to enhance learning for all.
- Create a comfortable learning experience for everyone.

Training Materials

Training materials should:

- Be easy to read for all attendees.
- Highlight the most important messages or needs.
- Be available for the trainees as notes or summaries.

Course Evaluation

Evaluation of training should be conducted regularly—preferably after every class or online training session—using a widely used model, such as the Kirkpatrick model of training evaluation. Evaluations should include:

- *Reaction:* Was the training appropriate? What did the learners like and dislike? Was the trainer skilled and successful? Would learners recommend others take the training?

  This information is often gathered with a form filled out by the trainees or a question and answer [Q&A) session at the end of training.
- *Learning:* What knowledge did the class members obtain?

  This is often ascertained through a short quiz or Q&A to measure learning at key points during the training session.
- *Behavior:* What actions are the trainees going take as a result of the course?

  This may be checked through a written objective or in a Q&A session at the end of the training session.

Post-Training Follow-up should also be done, often by a team of the trainees and/or by management several weeks or months after completion of the training. This evaluation should consider:

- What impact was achieved in the organization as a result of the training?
- Was a return on investment (ROI) identified?

Record Keeping

Records of training should be kept, including:

- Attendance records.
- Description of the content and activities.

Certificates of training completion and, if appropriate, Continuing Education Units

(CEUs) or Professional Development Hours (PDHs) should be presented.

CLOSING THOUGHTS
The Role of Training in Conveyor Safety

Effective training programs, including task training, are needed so that all workers are aware of hazards and know the procedures to safely perform their assignments. Training can prevent injuries, illnesses, property damage, and unnecessary interruptions in the production process.

Training is not a panacea, a universal cure for all safety issues. In a 2009 article, "Effects of Safety Training or Risk Tolerance: An Examination of Male Workers in the Surface Mining Industry," published in *The Journal of Safety, Health, and Environmental Research*, points out:

> Training coupled with the presence of a strong safety culture, motivating consequences, open safety communication, and supervisors with strong leadership skills may produce the desired safe work behavior, but training alone should not be relied upon to lessen a worker's tolerance for workplace risk.

Section 4

RISK ASSESSMENT

Chapter 27 The Conveyor Safety Census

INTRODUCTION

The danger areas of a conveyor system are numerous and specific to every application.

But too often, many of the details of a conveyor's specific safety hazards are not documented. Rather, these hazards are accepted in the facility. They are communicated as common knowledge and passed along like folklore from one worker to the next.

This folklore—this common knowledge—fades or disappears altogether. Plant ownership and management change; engineering, maintenance, and operations personnel change responsibilities or leave the company. Consequently the in-house knowledge of equipment systems—including conveyors—erodes.

Even the lists of the major components in the conveyor system will likely not have been kept up to date in the safety, engineering, purchasing, or maintenance departments. The files become outdated or, perhaps worse, the information is retained only in the mind of one person.

First Steps: Fact Finding

It is a good practice to conduct a safety assessment of a plant's conveyor systems. This census appraises the components and equipment installed on a conveyor and looks for the hazards that exist in the conveyor system.

It is best for this safety survey to be conducted by a team of at least two workers. This 'buddy system' helps to identify and rank issues found during the conveyor 'walk down,' and thus avoids reporting concerns that result from assumptions or misunderstandings. (**Figure 27.1.**) Ideally one person would be familiar with the conveyor and process being surveyed and the second person familiar with conveyors in general. Over-familiarity with the specific conveyor can result in walking by a problem. If the second member of the survey team comes from another part of the facility or is an outside contractor or consultant, this person provides a fresh perspective. In addition, the consultant provides a new frame of reference without preconceived notions as to why things are the way they are. This way the team is more able to see what can and should be done.

The conveyor safety assessment is usually conducted by 'walking the belt.' The safety team walks the system: inspecting its operation, performing minor safety adjustments, and noting more significant conditions or problems for later attention. During this safety

Figure 27.1.

The 'buddy system' of sending two workers as a team to inspect conveyors helps to identify and rank issues found during the survey.

What to Take When Walking the Belt

A key to having the right equipment when surveying the conveyor is to know the assignment: whether the walk is for purposes of safety assessment only, or whether other condition monitoring and minor maintenance chores, such as cleanup or idler lubrication, are required.

The following are recommendations for the appropriate equipment to be carried or immediately available on a conveyor safety assessment.

- A partner (A 'buddy' for the Buddy System).
- Anemometer, to check wind speed (for dust control).
- Belt speed tachometer (speedometer).
- Camera (or cell phone) for photos and/or video clips of equipment.
- Flashlight (explosion-proof light if required for conditions).
- Hand tools, including a hammer, an adjustable wrench, and a pair of pliers.
- Guard removal key or other specialized tool to remove guards, as may be required in the facility.
- Infrared non-contact thermometer, to check for overheated components or material.
- Means to record information: This might range from a pad of paper to a tablet computer.
- 'Repair Needed' tags (and/or 'Crime Scene'/unsafe area/caution tape).
- Safety census form to be completed, or for use as a guide of what to inspect.
- Tape measure or 'Gotcha Stick' to measure guard-to-hazard distance. (**See Chapter10 Guarding**.)

Of course, the equipment listed above is in addition to all personal protection equipment (PPE) required in the plant, and the appropriate communications equipment (for example, walkie-talkie).

Despite needing the proper tools, it is important that the 'belt walker' be unencumbered—so the worker can be safe and efficient during the walk.

Many plants have shovels and other cleanup equipment positioned at locations along the belt, so the belt walker usually will not need to carry those tools on the journey. The conveyor patrol might also be charged with the need to make small adjustments important to the life of the equipment and the efficiency of the operation.

census, potential hazards are observed, identified, and recorded.

The belt walkers should take notes of the problems observed. For example: 'There is an unguarded pinch point on the tail of Conveyor B that could result in an entrapment,' or 'There is a lot of spillage at the tail of Conveyor 3 that could cause a slip/trip/fall incident.'

It is better to make notes as the problem is seen rather than waiting until the inspection is finished on a particular conveyor. Information could be recorded on a pad of paper or a tablet computer. Even a cell phone can be used to call the conveyor inspector's own voice mail to record things noticed on the walk, especially those things that might be forgotten by the time the inspector returns to the office and is distracted and bombarded with other daily details.

A digital camera, cell phone, or even many tablet computers allow the inspector to take photos or video of problems. The belt inspector can then send the images of the problem to others in the organization for evaluation.

Once this information is collected, it should be archived in a single, central location and becomes the responsibility of the plant safety manager. This information can be used to educate those workers unfamiliar with an operation or equipment to prepare them for any dangers they may encounter.

Some specialized computerized systems allow the incorporation of materials into a digital asset library. This system becomes a centralized library for personnel to quickly access safety information associated with each conveyor.

Figure 27.2.

Extreme caution should be taken when inspecting conveyors while the belt is running.

Conveyor Up, or Conveyor Down?

The question of walking the belt and conducting a safety assessment of the conveyor when the system is operating, as opposed to walking when the conveyor is not running, is worthy of some consideration. Walking the system when the belt is moving allows the personnel to see more of the real problems that affect conveyor safety. If the conveyor is not moving, many key indicators are hidden, such as vibrations in the structure and fluctuations in the belt's line of travel. Some inspections and adjustments can be made only with the belt running. (**Figure 27.2.**)

Obviously, conveyors are safer when they are not running, and it is safer to do any corrective action on conveyors when they are not running. The person assigned to walk the belt should be experienced with conveyor systems, aware of the hazards, and trained and authorized to make a limited amount of corrections on an operating conveyor.

If time and personnel allow, it is a good idea to survey the conveyors under both conditions—that is, when the belts are running and when the belts are stopped. This will provide an improved understanding of the system under all conditions, without increasing the risks for plant personnel.

The decision as to whether to walk the belts when the conveyors are running or not may depend on external factors, such as when manpower is available and the level of service-work expected. Regardless, a significant amount of caution is advisable.

What to Do When the Census is Done?

More important than walking the belt is doing something with the information acquired on the trip. Recording the observations and then submitting them to the proper authorities is the reason the trip was made. The facility's safety personnel or plant management should be alerted to the specific safety hazards and risks uncovered by the survey.

Once all of the data is collected from a conveyor safety walk, it should analyzed; then it should be acted upon. Each of the observed problems can be evaluated, prioritized, and its root cause(s) identified by plant personnel or outside consultants. When the causes of problems have been identified, solutions should be arranged. Things that can be fixed immediately should be. Remaining concerns should be documented so proper resources can be allocated to provide the required solutions.

A 'walk the belt' safety inspection does not show how to solve the problems, but it is an invaluable tool used in the identification of problems, and thus a key step in the solving of those problems.

With good records of the concerns noted on a conveyor walk—or better yet, a regular series of conveyor walks—the operation has the opportunity to prevent safety problems rather than react to them. That is the real benefit of any walk of the conveyor system.

A thorough conveyor safety survey completely identifies most of the safety concerns of a conveyor. Regular walks keep the impacts of system changes to a minimum, and the actual act of walking the conveyor keeps safety in the minds and eyes of the employees. This is a very effective way to ensure management commitment and a very visible way to promote a culture of safety.

BEST PRACTICES
Conveyor Safety Audit

- Survey as a team, with one person familiar with the day-to-day operation and maintenance of the conveyor and a second person with general knowledge of conveyor design but not the specifics of the conveyor being surveyed.
- Make notes to document findings, place 'Repair Needed' tags, take pictures, and keep records.
- Prioritize hazards in terms of the likelihood of occurrence and the severity of harm.
- Take immediate action to mitigate potential hazards. It is a good practice to have a maintenance team or contractor staffed and pre-authorized to take action to resolve the root causes of safety concerns.
- Authorize the survey team to issue 'stop work' orders if the team finds a problem(s) of immediate danger. (**Figure 27.3.**)

CLOSING THOUGHTS

Everyone who works around conveyors knows—or should know—that conveyor belts are dangerous. Yet in spite of this knowledge, workers are still maimed and killed by conveyors every year. Despite the posting of signage, the proclamation of edicts, and the establishment of safe work procedures, experience has proved that these methods are not totally effective in eliminating conveyor accidents. These methods are undermined by the inherent dangers of a conveyor system, the unsafe work practices of the workers, and their focus away from safety.

Unless these issues are addressed in a thorough and honest manner, there will still be injuries, and even fatalities, around belt conveyor systems. ⚠

Figure 27.3.

The conveyor survey team should be empowered to stop the conveyor if an immediate danger is identified.

4

Chapter 28

Risk Assessment Using CEMA Methodology

INTRODUCTION

Conveyor design, specification, procurement, installation, commissioning, and operation are a complex stream of interactions between many different stakeholders with differing levels of education and sophistication, so numerous ethical and legal issues can arise. Usually several levels of contractual relationships add to the complexity. This increases the opportunity for critical decisions to be based on incomplete information or misunderstandings between parties.

With **Production Done Safely™** as the primary objective, it is important and cost-effective to expose ethical and legal issues as early in the project development as possible. Since conveyor systems are often integrated into processes, the possibility of correcting defects becomes prohibitively expensive and, in many cases, physically impossible to correct after the system is installed and operating. (**Figure 28.1.**) Human nature often makes doing the right thing the most difficult thing to do, even when it is the obvious path. Conflicts between personal and professional value systems and, when they exist, corporate ethics statements are common leaving a person in an ethical dilemma. Often the choice is between doing what is right with the perceived risk of 'costing too much' or losing one's job. Sometimes the ethical choice results in additional work or delays, and through a process of irrational rationalization the less ethical choice is made.

Many myths and misunderstandings exist about legal and ethical issues. This provides a false sense of absolution of risk and results in design and construction shortcuts that on their face save money but in the long run are costly. There are two basic legal systems, case law and statutory law. Each contract disagreement or effort to seek compensation for injuries often involves many differences of opinion, uncertainty of facts, and legal complexities making it difficult—if not impossible—to isolate one's self from some liability.

'Safety First' and 'Safety is Your Responsibility' are both fallacies and are, therefore, intuitively rejected by workers even though they give tacit support to these slogans—primarily to gain favorable evaluations of their attitudes from management. 'Safety First' is a fallacy because the reason a conveyor is built is for production, not safety, and this is reinforced by management in words and actions.

Individual responsibility for safety is a valid accident-mitigation approach only if the employee has the authority for safety. An analogy would be holding the plant manager responsible for production but giving him no authority to authorize production expenses. It seems unproductive (and unfair) for a person to be held responsible for safety, yet be given no authority and no budget to rectify safety issues. Usually, the production and maintenance workers have no budget line items which they control. Even when they have some authority to spend money, it is often such a low amount or requires so many layers of approval that workers quickly get the message that their budget is just window dressing to make management able to check the employee empowerment box on their self-evaluation form.

Most current safety laws were written in the 1970s, and since then have been updated mainly to increase penalties but not necessarily to keep up with changes in technology and changing social expectations. Laws and regulations are difficult to enact or amend and usually represent or include political compromises. Standards developed by industry associations are updated frequently and often contain current best practices based on practical application.

One cannot insulate oneself from liability based on just meeting minimum safety regulations. Courts and juries tend to look at an injury claim based on current social norms and state-of-the-art industry best practices, which almost always create a higher standard than laws and regulations.

Conveyor systems are often designed in one country, fabricated in another, and installed in a third. Used conveyor systems are often sold, modified, and operated (and possibly misapplied) without the knowledge of the original designer or manufacturer. Legal systems and laws differ from region to region and even within different districts, states, or cities within the same region.

In risk assessment, the level of risk is a function of the severity of the possible injury—the worst possible consequence of exposure to the

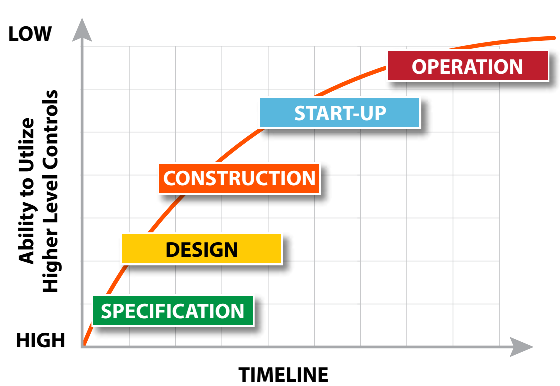


Figure 28.1.

Changes to improve safety are more difficult as the project progresses.

hazard—and the probability of occurrence. One matrix for risk assessment is presented in *ANSI B11.TR3 Risk Assessment and Risk Reduction—A Guideline to Estimate, Evaluate and Reduce Risks Associated with Machine Tools* This technical report presents a methodology for conducting risk assessment and addressing the assessed risk with a suitable safety system. (**Figure 28.2.**)

Figure 28.2.

Risk Estimation Matrix. After Schmersal Inc.'s U.S. Guidelines for Risk Assessment.

Probability of Occurrence	Severity of Injury			
	Minor	Moderate	Serious	Catastrophic
Remote	Negligible	Negligible	Low	Low
Unlikely	Negligible	Low	Medium	Medium
Likely	Low	Medium	High	High
Very Likely	Medium	Medium	High	High

Recommended CEMA Risk Assessment Process

The remainder of this chapter presents the risk analysis methodology recommended by the Conveyor Equipment Manufacturers Association (CEMA), as published in *CEMA Technical Report 2015-01 Recommended Risk Assessment Process*. This methodology is offered as a service to the industry and is available as a free download (PDF) from the CEMA website, *cemanet.org*.

The CEMA Risk Assessment Process is also published (in a slightly different format) in the 7th Edition of the CEMA reference *Belt Conveyors for Bulk Materials*. It has been incorporated by reference into *ASME B20.1-2015 Safety Standard for Conveyors and Related Equipment*.

The CEMA Risk Assessment Process *is reprinted with permission of the Conveyor Equipment Manufacturers Association; all rights reserved.*

Risk Assessment

Risk can be defined as a combination of the probability of occurrence of harm and the severity of that harm. Risk assessment can be applied to personnel, property, environmental and societal events and their consequences. Reactively evaluating risk and dealing with the consequences through a variety of mitigation techniques is common in bulk material handling. What is not common is a standardized proactive approach to reducing risk through the use of a defined risk assessment and solution implementation process. (**Figure 28.3.**)

There are many terms used interchangeably with the term Risk Assessment. Risk Assessment in this book is defined as the process of reducing the probability and severity of harm to people, and/or the environment and/or property to an acceptable level through the use of a defined process. A defined risk assessment procedure is useful in identifying risks that can be mitigated at each stage of use of a product or service. Mitigating hazards by design or eliminating them by substitution is recognized as the most effective way to improve safety. (**Figure 28.4.**)

The risk assessment described here focuses on eliminating risk through mitigating the hazard or hazardous situation as it applies to systems, components and activities. Risk assessment is most commonly done by a team of stakeholders and usually results in identifying and reducing risks that the manufacturer, engineer, supervisor or worker may not identify or consider a serious hazard by themselves.

Each stakeholder at each stage of use of a product, system or service should perform a risk analysis. For example: the designer or manufacturer can assess risk on the equipment or activity as they foresee the reasonable intended use of their product or service. However, the designer or manufacturer often does not control the installation, integration of their equipment into a process, training on proper use or maintenance, or the use of product or service on site, requiring further hazard identification and mitigation. Job Safety Analysis is a form of risk analysis that is most effectively completed by those at the point of installation, use or maintenance. It is often said that the fact that risk analysis is done is more important than which risk assessment format that is used.

At the time of printing there are no government mandated standards that must be used for risk reduction in general bulk material handling operations. Therefore, it is up to each stakeholder's management to establish and implement a risk reduction methodology. In this document, *ANSI B11.TR3-2000* and *MIL-STD 882* are used as reference documents for developing an example risk assessment methodology with additional suggestions for considering risks unique to your particular conveyor and conveyor installation.

Acceptable Risk

The goal of a risk assessment is to reduce residual risks after analysis and implementation, to an acceptable level. Zero risk is impossible to obtain. Acceptable risk is a subjective concept which is defined by the risk assessment team often within established policy. Many risk assessment systems use the concept of residual risk as being acceptable if it meets a test of As Low As Reasonably Possible, ALARP.

Determining ALARP is almost always a subjective judgment made by a team formed from a range of skill sets within the context of their

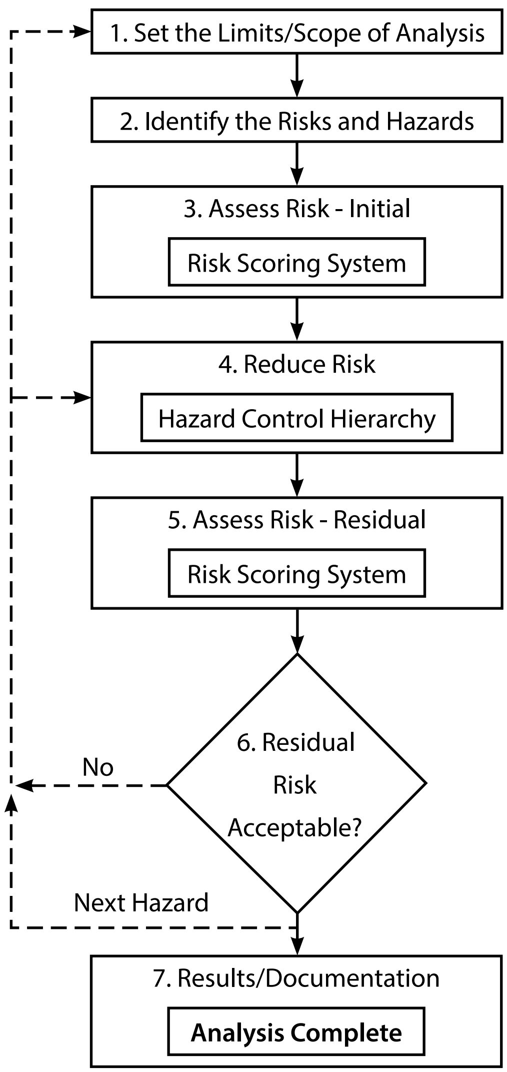


Figure 28.3.

CEMA general risk assessment process.

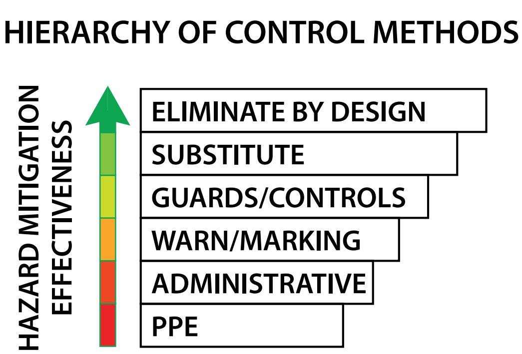


Figure 28.4.

Effectiveness of risk mitigation efforts, as shown in the CEMA Risk Assessment Process.

United States Department of Defense Military Standard (*MIL-STD-882*) presents a Standard Practice for System Safety

The CEMA Risk Analysis Procedure as published here and in Belt Conveyors for Bulk Materials cites *MIL-STD-882* as a standard methodology for system safety. The following is the description of this procedure and program, as available from the Department of Defense. In 2012, *MIL-STD-882E* superseded *MIL-STD-882D*.

The U.S. Department of Defense's (DoD) military standard *MIL-STD-882E* outlines a standard practice for conducting system safety, and it provides a consistent means of evaluating risks. Mishap risk must be identified, evaluated, and mitigated to a level that is acceptable to the appropriate authority and is compliant with federal laws and regulations, executive orders, treaties, and agreements. Program trade studies associated with mitigating mishap risk must consider total lifecycle cost in any decision.

The *MIL-STD-882E* standard defines general safety requirements to perform throughout the lifecycle for any system, new development, upgrade, modification, resolution of deficiencies, or technology development. When properly applied, these requirements should ensure the identification and understanding of all known hazards and their associated risks, and mishap risk will be eliminated or reduced to acceptable levels.

General system safety requirements include:

1. Documenting the system safety approach.
2. Identifying hazards.
3. Assessing mishap risk.
4. Identifying mishap risk mitigation measures.
5. Reducing mishap risk to an acceptable level.
6. Verifying mishap risk reduction.
7. Reviewing hazards and accepting mishap risk by the appropriate authority.
8. Tracking hazards, their closures, and mishap risk.

Minimum mandatory requirements for an acceptable safety system for any U.S. DoD system are also delineated in the standard.

The U.S. DoD's military standard *MIL-STD-882E* is available for complimentary download.

operation. If one member or group of the team dominates the judgment on a particular point the result may not be reasonable so it is important to have a cross section of skill sets in the risk assessment team with a method of reaching consensus. The team should reach some definition of ALARP risk before starting the process. It is not necessary to address every risk the team identifies as some risks may be so remote or redundant that it would be a diversion from resolving the significant risks.

Minimal risks that evolve into significant risks in the future or new risks that are introduced can be identified if risk assessment is considered a continuous improvement activity and performed periodically. The absence of qualitative data in ranking risk is not as important as the team's perception of the risk and their solution because data on specific hazards is almost never available for bulk-materials-handling operations and those involved daily with the risk are often the experts in resolving them. Teams can always seek outside expert advice if they become deadlocked or need specific expertise.

MIL-STD 882

MIL-STD 882 can be downloaded for free and used as a guide. There are many other risk assessment approaches readily available. There is no right or wrong approach. The important point is to have a defined system that works for your operation and make it part of your safety culture. The basic approach in all risk assessment systems is to list all of the hazards, hazardous conditions or at risk behaviors that the team can readily identify. Brainstorming techniques are useful in this part of the process. Once a list is generated, each hazard is rated for severity and probability of occurrence. (**Figure 28.5.**) The combination of severity and probability is given a rank. (**Figure 28.6.**) Alternative means of reducing the risk are evaluated and scored until the ranking is within the team's ALARP definition. (**Figure 28.7.**) In some cases the risk cannot be reduced to an ALARP level through design or substitution. In those cases, alternate approaches such as additional training or engineering controls can be used to mitigate the risk.

Obviously, for the hazards identified in the assessment to be effectively mitigated, the solutions must be implemented for them to become effective. Documenting the results is strongly suggested so that improvements can be monitored and goals for mitigation of risks adjusted if necessary. The most effective systems implement changes as quickly as possible, often through empowerment of the risk assessment team to take immediate action.

Risk Assessment Matrix				
Probability / Severity	**Catastrophic (1)**	**Critical (2)**	**Marginal (3)**	**Negligible (4)**
Frequent (A)	High	High	Serious	Medium
Probable (B)	High	High	Serious	Medium
Occasional (C)	High	Serious	Medium	Low
Remote (D)	Serious	Medium	Medium	Low
Improbable (E)	Medium	Medium	Medium	Low
Eliminated (F)	Eliminated			

Figure 28.5.

The Risk Assessment Matrix as seen in MIL-STD 882 *assigns a risk level for each combination of Severity and Probability..*

Description	Category	Definition
Catastrophic	I	Could result in death or permanent total disability, loss exceeding $1,000,000 or irreversible severe environmental damage that violates law or regulation.
Critical	II	Could result in permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, loss exceeding $200,000 but less than $1,000,000 or reversible environmental damage causing a violation of law or regulation.
Marginal	III	Could result in injury or occupational illness resulting in one or more lost work day(s), loss exceeding $10,000 but less than $200,000 or mitigatable environmental damage without a violation of law or regulation where restoration activities can be accomplished.
Negligible	IV	Could result in injury or illness not resulting in lost work day, loss exceeding $2,000 but less than $10,000 or minimal environmental damage not violating law or regulation.

Figure 28.6.

Suggested mishap probability levels as adapted from MIL-STD 882.

Probability	**Severity**			
	Catastrophic (I)	**Critical (II)**	**Marginal (III)**	**Negligible (IV)**
Frequent (A)	1	3	7	13
Probable (B)	2	5	9	16
Occasional (C)	4	6	11	18
Remote (D)	8	10	14	19
Improbable (E)	12	15	17	20

Figure 28.7.

Mishap Risk Assessment Matrix Results with Numerical Values.

4

Example: Severity vs. Probability ALARP Matrix

Using CEMA's methodology, the authors have provided an example that is somewhat different than the on presented in the *CEMA Book*.

Management forms a risk assessment team and provides some guidelines. Management sets the risk level as low as reasonably possible as shown in **Figure 28.7** and **Figure 28.8.** The team determines that they will use a combination number and letter ranking rather than all numerical values as shown in **Figure 28.7.** For example, a hazard or work practice that creates a hazardous situation with consequences judged by the team to have marginal consequences [Marginal (III)] and is judged by the team to 'probably' occur [Probable (B)] over the life of the equipment would be ranked III-B. (**Figure 28.8.**)

Management determines that for the matrix in **Figure 28.8**, the following criteria as shown in **Figure 28.9**) apply:

As **Figure 28.3** shows, risk reduction or elimination is an iterative process. In this hypothetical scoring system the team has, in effect, been tasked with reducing risks into the shaded area of **Figure 28.8** and given authority by management to incur up to $10,000 to reduce identified risks within the scope of the assignment.

The team decides to focus on the risks associated with the common practice in the plant of taking a short cut by crossing under a conveyor. (**Figure 28.10.**) The particular crossing is located where it is necessary for some workers to duck to avoid contact with the structure or moving belt.

The team developed a list of potential hazardous situations using brainstorming techniques and ranked them by severity and probability. (**Figure 28.11.**) It is more important that the hazard list identify the most consequential hazardous conditions and possible outcomes than it is to list every possible scenario. If good safety and design review processes are in place, there will be additional risk analysis reviews before the team's final proposal is accepted and implemented.

Comparing the team's assessment with management's ALARP matrix (**Figure 28.12.**), the team concludes that the crossunder location needs to be moved and redesigned.

The team recommends that the travel paths be controlled using handrails, a formal cross-under with spill protection be installed, traffic control signs and guard rails installed and the area lighted at night. (**Figure 28.13.**) The result will be a minor inconvenience to workers traveling under the conveyor but it greatly reduces the severity and probability of accidents.

4

Figure 28.8.

Hazard Risk Assessment Ranking.

Probability of Event "X" Occurring	Severity of Consequences of Event "X" Occurring			
	Catastrophic (I)	Critical (II)	Marginal (III)	Negligible (IV)
Frequent (A)	I-A	II-A	III-A	IV-A
Probable (B)	I-B	II-B	III-B	IV-B
Occasional (C)	I-C	II-C	III-C	**IV-C**
Remote (D)	I-D	II-D	**III-D**	**IV-D**
Improbable (E)	I-E	**II-E**	**III-E**	**IV-E**

Figure 28.9.

Management Criteria for ALARP Risk Acceptance.

Risk Ranking Scores	Action
I-A, I-B, I-C, II-A, II-B, III-A	Unacceptable: eliminate, substitute, or redesign
I-D, I-E, II-C, II-D, III-B, III-C, IV-A, IV-B	Undesirable: review risk reduction plan with management
II-E, III-D, III-E, IV-C, IV-D, IV-E	Acceptable: management review if cost is > $10,000

The team works with the maintenance department and comes up with a plan for making the changes taking into account the needs of all that would use the cross under. The team also re-evaluates the Severity vs. Probability matrix with the conclusion that their re-design meets management's requirement of ALARP risk. The process is documented and the changes are implemented.

Figure 28.10.

Crossing under a conveyor is a risky behavior that can lead to injury.

	Hazard	Resulting Event	Severity	Probability
1	Carryback accumulation under conveyor	Slip on carryback – possible back injury	II	A
2	Carryback accumulation under conveyor	Trip on carryback – reach for hand hold – possible laceration or fall	II	A
3	Carryback accumulation under conveyor	Walk on pile – return roll no longer guarded by position – Nip point exposure	I	C
4	Low clearance catwalk structure	Hit head - laceration possible if not wearing hard hat	III	B
5	Traffic along both sides of conveyor	Walk into traffic without yielding – pedestrian/vehicle accident	I	D
6	Belt overloaded or mistracking	Falling material from above – injury from falling material and additional accumulation causing slips and trips	II	C
7	Poor visibility at night or severe weather	Slip or trip possibility of increased pedestrian/vehicle accident	I	C

Figure 28.11.

Risk Assessment Severity and Probability List for the example.

Probability of Event "X" Occurring	Severity of Consequences of Event "X" Occurring			
	Catastrophic (I)	Critical (II)	Marginal (III)	Negligible (IV)
Frequent (A)	I-A	II-A	III-A	IV-A
Probable (B)	I-B	II-B	III-B	IV-B
Occasional (C)	I-C	II-C	**III-C**	IV-C
Remote (D)	**I-D**	**II-D**	III-D	IV-D
Improbable (E)	I-E	II-E	III-E	IV-E

Figure 28.12.

Risk Assessment Severity and Probability Ratings for the example.

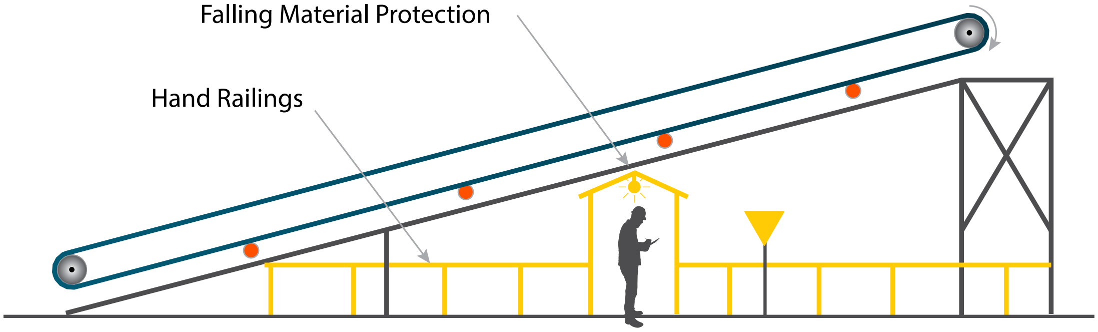


Figure 28.13.

System Redesign to Reduce Severity and Probability for the example.

4

Introduction to Appendices

ANSI B11.TR3 – 2000 Risk Assessment and Risk Reduction – A Guideline to Estimate, Evaluate, and Reduce Risks Associated with Machine Tools, lists typical hazards and hazardous situations in the design, installation, use and maintenance of machine tools.

There are hazards and hazardous situations specific to typical bulk material and unit handling systems, components and maintenance that need to be identified in addition to those listed in *ANSI B11.TR3 – 2000*.

Each design firm, manufacturer, installer, user and maintenance operation should develop a check list of hazards and hazardous situations unique to their situation.

The following Appendices are provided as suggested starting points for developing a list of hazards that are common to all belt conveyors (**Appendix 1**) and those specific to bulk belt conveyors (**Appendix 2**).

CEMA Risk Assessment Appendices 3, 4 and 5 are for unit, screw and bucket elevators and are not included here. These appendices are not intended to be an all encompassing list.

The list should be used as a supplement to other commonly available lists, such as those in *ANSI B11.TR3 – 2000* and *MIL-STD 882*, and modified for each specific material handling operation. The *ASME B20.1* and *ISO 5045* Standards are recommended as sources of additional identified hazards.

There are often many types of process equipment and haulage systems in the proximity of conveyors that potentially represent significant hazards. The hazards they present should be considered in addition to simply analyzing the movement and storage of the material being conveyed on the conveyor.

Regulations pertinent to the specific industry are another source of specified risks that can be added to check lists to customize the risk assessment process.

[Appendix 1 and Appendix 2 from *CEMA Technical Report 2015-01* are related to bulk material belt conveyors and are shown here. Appendices 3, 4, and 5 in the *Recommended CEMA Risk Assessment Process Technical Report 2015-01* deal with Unit/Package Conveying, Screw Conveyors, and Bucket Elevator Conveyors respectively, and so are omitted here. – Ed.]

Appendix 1

Examples of Common Hazards and Hazardous Situations for All Conveyors and Conveying Systems.

Ref #	Hazard or Hazardous Situation, Item or Event
1	**Site Conditions**
	Falling return idlers, components or conveyed product
	Wet or slippery surfaces
	Relative location of aisle ways and pathways
	Untrained personnel
2	**Installation or Integration and Start up**
	Incomplete specifications or instructions
	Missing components or software for system or process
	Installation labor not trained on specific requirements
	Wrong components delivered or parts missing
	Scheduling conflicts
	Run-in issues with components or control systems
3	**Components**
	Frictional heating from frozen component against moving belt
	In running nip points between belt and rotating components
	Crushing between moving and fixed components
	Applying belt dressing to drive pulley
	Backstop or holdback failure
	Hot surfaces - gearboxes and motors
	Significant quantity of bearings
	Key seat or set screw snag points

4

Ref #	Hazard or Hazardous Situation, Item or Event
4	**System**
	Elevated systems and walk ways (egress per local and federal standards)
	Location of controls
	Crossover or crossunder conveyor
	Moving transfer points
	Plugged chutes
	24/7 operation
	Portable conveyors
	Belt tracking
5	**Maintenance**
	Welding and cutting
	Manual lifting and positioning of heavy components in restricted spaces
	Confined spaces
	High pressure fluids and gasses used
	[Lockout / Tagout / Blockout / Testout (LOTO/BOTO)]
6	**Controls**
	Proper interlocking
	Pull cord and E-stop switches
	Remote automated sequential starting
	Local disconnect switch
	Convenience of [LOTO/BOTO] location
	Unexpected Startup – Restoration of Energy after Interruption
	Software errors
7	**Cleaning**
	Strains, slips and falls
	Long handled and sharp tools
	Compressed air or high pressure water used for cleaning
	Recovering of product from return belt or pulleys with conveyor operating
	[Lockout / Tagout / Blockout / Testout (LOTO/BOTO)]
8	**Environment**
	Noise and dust
	Low light conditions
	Burns or scalding from contact with hot surfaces
	Other external influences (gravity, wind, etc.)
9	**Guarding**
	Guard opening to hazard distance
	Guard too heavy or has sharp edges

Ref #	Hazard or Hazardous Situation, Item or Event
	Guards at Nip Points: pulleys, idlers, convex curves, takeups and counterweight drop zones
	Guard size - reach distance to hazard
	Lubrication fittings external of guard
	Use of tools to remove
	Color
	Warning Labels
10	**Electric Shock**
	Energized live exposed parts
	Lack of earth grounding
	Shorts, arcing, sparking
	Improper wiring
	Static buildup and discharge
11	**Slip/Trip Falls**
	Fall from elevated work (fall protection)
	Misuse of climbing on conveyor
	Falling material from conveyor surface
	Spilled product or debris
	Uneven walking surfaces
12	**Noise/Vibration**
	Noise or sustained sound pressure levels >85 dBA
	Noise or instantaneous sound pressure level >120 dBA
	Interference with communications
	Fatigue and alertness of operators
13	**General**
	Lock Out Tag Out Try Out procedure
	Loose clothing, hair, jewelry
	Heavy equipment with limited driver visibility
	High voltage motors and electromagnetic fields
	Pressure – hydraulic or pneumatic component rupture
	Structural members – fatigue, corrosion, rupture
	Unexpected Startup or Motion during jam clearing or maintenance
	Loss of communication with machine that affects stopping or control

Appendix 2

Examples of Hazards and Hazardous Situations in Bulk Belt Conveying.

Ref #	Hazard or Hazardous Situation, Item, or Event
1	**Belt**
	Protrusions, flaps or long sections of ripped conveyor belt
	Mechanical splices with protruding or loose components
	Hypnotic effect of moving belt and rotating components
	Walking on stationary or moving belt
	Riding on belt
	Stored energy, potential energy in belt, slack in the belt
	Static charge build up
	Sloped belt or belt splice failure
	Belt mistracking
	Belt fire
	Moving belt with no motion markers
	Stored energy in pulling cable during belt installation
	Failure of belt clamp during installation or splicing
	Energy stored in belt and components during clearing jams by jogging the belt
	Vibration in steel cord belt
2	**Bulk Material**
	Respirable dust
	Explosive dust
	Spontaneous combustion
	Large lumps falling or projected from conveyor
	Potential energy of material accumulated on stationary belt, structure or in bins
	Caustic or acidic bulk materials
3	**Site Conditions**
	Open tip hoppers, bins, silos
	In ground pits and receiving hoppers
	Fire and/or explosion from accumulation of combustible fines
	Electrical classification
	Waste water and drainage systems
	Uneven and/or unpaved surfaces

Ref #	Hazard or Hazardous Situation, Item, or Event
	Dust control
4	**Components**
	Falling gravity takeup
	Magnetic fields from tramp metal magnets
4	*continued ...* **Components**
	Radiation exposure from nuclear measuring devices
5	**System**
	Tunnels and enclosed galleries with limited space between belt and access
	Spillage and carryback
	Build up of bulk materials on rotating components or tracks
	De-icing
	Unguarded portions of conveyor by rule i.e. skirtboard seal and belt
	Exposed to weather extremes
6	**Installation or Integration and start up**
	Test bulk material not same as production material
7	**Stockpiles**
	Mobile equipment traffic patterns
	Highwall failures
	Crusted bulk materials with opening or void below
	Open unguarded draw down into feeder
	Stockpile level control failure
	Slope stabilization during reclaim operations
	Dust control
	Spontaneous combustion of product

4

CLOSING THOUGHTS

The Importance of Risk Assessment

The assessment of risk is an important and primary step in reducing accidents and injuries. A proper procedure, properly followed, will help industrial operations prioritize and correct hazardous situations, improve worker safety, and prevent unnecessary accidents.

Always remember that one cannot insulate oneself from liability based on just meeting minimum safety regulations. Courts and juries tend to look at an injury claim based on current social norms and state-of-the-art industry best practices, which almost always create a higher standard than laws and regulations. ⚠

Chapter 29 Root Cause Analysis

INTRODUCTION

Human error is commonly defined as the failure of a planned action to achieve a desired outcome—without the intervention of some unforeseeable event. In this book, the authors argue against explaining 88 percent of accidents as caused by human error. Blaming the worker for an unsafe act and closing the investigation without inquiring further is all too common and often fails to consider the complexity of human interactions with systems.

The 'unforeseeable event' qualifier above is important in accident investigation. Very few accidents can be explained away as sabotage or as the result of an intentional unsafe act. Accident investigation will often show that the worker(s), in the sequence of events leading up to the accident, made decisions that were either logical at the time or in accordance with standard procedures.

Accident Investigation

From the work of H.W. Heinrich, who in 1931 was the first to analyze a large database of industrial accidents, comes the still widely held belief that the root causes of 88 percent of all accidents are unsafe actions of the worker. Most of the remainder of accidents stem from exposure to unsafe mechanical conditions—which are also the fault of people. Heinrich's groundbreaking book, *Industrial Accident Prevention*, has been reprinted several times, and the most recent printing interjects current accident cause and mitigation thinking in a way that makes it difficult to determine Heinrich's original intent. But it is clear that many managers and safety authorities still hold to the theory that the worker is approximately 88 percent or more of the problem.

In hindsight, it is easy to say that, if not for the unsafe act, the accident could not have happened and, therefore, the root cause is worker incompetence. However, this conclusion requires the reasoning that had the worker known the outcome of the actions and the circumstances, the worker would do exactly the same thing again and knowingly suffer the consequences of the accident.

Analysis of a safety incident or a property incident, such as a machine breakdown, can often also be falsely explained away by simply blaming the worker's knowledge or quality of work. This is the fallacy of hindsight; knowing the outcome makes blaming the worker an easy conclusion, because it is obvious that without the worker's action the accident or production stoppage would not have happened.

In reality, conveyors are complex systems and humans are complex beings, and this complexity usually means that there are multiple influences that make finding one simple and easily correctible root cause unlikely. Workers do not purposely injure themselves. They make the best decisions they can at the time, based on the information available and in their immediate environment. All the while they balance multiple, and often conflicting inputs, including machine condition, control system data, co-workers suggestions, company policies, plant rules, management styles, and personal and corporate goals.

Root Causes Related to Conveyor Injuries and Property Damage

Worker at-risk behavior is often a contributing factor to accidents, but may not be the primary or root cause. The actual root causes of an accident are often:

1. Company Culture
2. Design
3. Maintenance
4. Complexity
5. At-Risk Behavior

Company Culture

Company culture is often the primary but most difficult to accept root cause of many mishaps. Perhaps this is easier to understand when thinking of unplanned outages. A culture that runs equipment beyond its limits and reduces the time and resources available for maintenance sends a powerful message that production is the most important activity management values. (**Figure 29.1.**)

Similarly, a company culture that buys equipment based on price rather than on value or suitability for the intended use is less likely to value training or employee development. In this culture, employees will take shortcuts and take risks to keep the equipment running.

Figure 29.1.

Graffiti like this indicates that when plant management reduces the time and resources available for maintenance, it sends a powerful message to the workforce.

4

Design

The same culture that overtaxes its equipment and people is likely to buy equipment on low bid without considering the effect on the supply chain. When lowest price is the criteria, design firms must reuse old design details to be competitive. In this case, these design firms might not have the profit margin needed to send their designers to the field to see firsthand the problems that their designs create.

Design is an iterative process of continuous improvement, and if the link between the design office and the reality of the field is broken, it is highly likely preventable errors are repeated. Sometimes the result is an inability to reach capacity or premature equipment failure; sometimes the result is a personal injury. Design is often the lowest-cost element in the supply of plant and equipment. Buying on price alone is a common root cause of poor performance and personal injury.

Maintenance

Many maintenance workers are good at creatively solving problems. However, if there are too few maintenance personnel for the amount of repairs required for the plant systems to run at optimum, the maintenance workers are likely to apply temporary solutions to the symptoms of the problem and not address root causes. (**Figure 29.2.**)

Many maintenance crews are not trained on conveyor systems and work from tribal knowledge—unwritten, informally shared 'rules of thumb' and folklore, information known but yet undocumented—without really understanding the overall effects on the system.

Figure 29.2.

Faced with too few maintenance personnel for the amount of repairs required, workers may apply temporary solutions to the symptoms, rather than address the root causes of a problem.

With a lack of specific knowledge even the most creative and hard-working maintenance people often treat symptoms and do not know how to address root causes.

Complexity

Conveyors are complex and dynamic machines. A simple in-plant conveyor can have over 10,000 moving parts. Latent defects are often exposed when conveyors are run over capacity, or when changes are made without understanding the interaction of all components.

At-Risk Behavior

Finally, the worker, who is often blamed for an accident, is sometimes the main root cause of an accident or incident. But, in many cases a worker—faced with a culture that values production over safety, the emphasis of short-term financial results over long-term gains, and suffers a lack of training on the unique components and complexity of conveyors—has made a reasoned decision between risk and reward when encountering a hazard.

Root Cause Analysis

Root Cause Analysis is a method of problem solving that tries to identify the root causes of faults or problems. The classical definition of a root cause is a cause that if removed from the fault sequence—that is, the problem—prevents the final undesirable event from recurring.

A causal factor is a factor that affects an event's outcome but is not a root cause. Though removing a causal factor can benefit an outcome, it does not prevent its recurrence for certain.

Since a specific accident or production problem cannot be investigated before the problem occurs, Root Cause Analysis is a reactive method of accident investigation.

The Classical Approach

The classical approach to Root Cause Analysis includes these general principles:

4

1. The primary aim of Root Cause Analysis is to identify the factor(s) that resulted in the type, magnitude, location, and timing of the harmful outcome(s).
2. Root Cause Analysis must be performed systematically, usually by a team of investigators, with conclusions and root causes that are identified and backed by documented evidence.
3. There may be more than one root cause for an event or a problem.
4. The analysis should establish a sequence of events or time line to understand the relationships between contributory factors and root cause(s).

Knowing the root cause(s) is secondary to the goal of prevention, but without knowing the root cause, it is not possible to determine an effective corrective action.

In well-managed companies with a strong safety culture, corrective action is a part of the continuous improvement process and the ultimate goal. Companies with a strong safety culture realize that safety is a benefit from solving root causes, and those benefits are realized through fewer and less severe accidents, higher production, and increased financial performance. These companies realize that safety is a continuous improvement opportunity.

At the other end of the spectrum, for some companies, the root cause report is the end in itself. Here, real correction actions are not a priority, and the practice of treating symptoms rather than causes continues. Excuses abound for treating the symptoms, including 'Not enough time to do it right,' 'Not in the budget,' or 'We tried fixing the problem before and it is easier to manage around it.' The unfortunate result from treating symptoms—instead of solving basic problems—is the probability is so high that the same or a similar problem will occur, it is almost guaranteed to happen. Of course, this costs more injuries, more lost production, more cleanup, and/or similar accidents.

The root cause investigation should be separated from the suggestions for corrective actions because local politics or constraints may influence the results. For example, if the actions or instructions of the supervisor or a management policy are identified as a root cause, the practical problems of corrective action may make the investigator hesitant to point it out. In many companies, the supervisor is the lead investigator. In this case, how likely is it that the 'investigator' will blame the supervisor—or the manager—as a root cause or even a causal factor? (**Figure 29.3.**)

A Process for Root Cause Analysis

The traditional general process for corrective actions based on Root Cause Analysis include these steps:

1. Define the problem or describe the event to prevent in the future. Include the qualitative and quantitative attributes (properties) of the harmful outcomes.
2. Gather data and evidence, classifying it along a time line of events to the final failure or crisis. For every behavior, condition, action, and inaction, specify in the time line what should have been done when it differs from what was actually done.
3. Ask 'why' and identify the causes associated with each step in the sequence towards the defined problem or event. 'Why' should be taken

Figure 29.3.

Finger-pointing at management, or at other workers is unlikely to get to the root causes of a problem.

to mean 'What were the factors that directly resulted in the effect?'

4. Classify these events into causal factors—factors that contribute to the problem(s)—and root causes—that lead directly to the problem(s).
5. Identify any other harmful factors that have equal or better claim to be called 'root causes.' If there are multiple root causes, as is often the case, explore those clearly for later optimum selection.
6. Check that each corrective action would, if implemented before the event, have reduced or prevented specific harmful effects.
7. Identify solutions that are within the institution's control, meet its goals and objectives, and do not cause or introduce new or unforeseen problems.
8. Implement the recommended root cause correction(s).
9. Follow up to ensure the corrective action was effective and no unintended consequences resulted.
10. Document the findings and formally close the analysis.

Determining Root Causes

The goal of finding root causes is not to place blame, but to solve problems. The easy way out is to blame the worker for committing an unsafe act. Reaching this conclusion would require the assumption that the worker, knowing the outcome of the actions, would commit the unsafe act again and again. Therefore, the solution is worker discipline, retraining, and, if all else fails, termination of employment. This 'worker is the problem' finding has its roots in Heinrich's work from the 1930s and ignores

The '5 Whys' Technique

The '5 Whys' is an iterative interrogative technique used to explore the cause-and-effect relationships underlying a particular problem. To determine the root cause of a problem, the primary method in the technique is to repeat the question 'Why?' Each question forms the basis of the next question. The '5' in the name derives from an observation on the number of iterations typically required to resolve the problem or to get to a root cause.

The technique was originally developed by Sakichi Toyoda and was used within the Toyota Motor Corporation during the evolution of its manufacturing methodologies. It is a component of problem solving incorporated in the Toyota Production System. The tool has now seen widespread use beyond Toyota, and within the Kaizen, lean manufacturing, and Six Sigma methodologies.

In some cases, the questioning could be taken further to a sixth, seventh, or higher 'Why?' But it is assumed five levels of asking 'Why?' is generally enough to get to a root cause. The key to success is to encourage the troubleshooter to avoid assumptions and logic traps, and instead trace the chain of causality from the effect through any layers of abstraction to a root cause that still has some connection to the original problem.

Example of '5 Whys' Technique

First Why	The belt is mistracking.
Second Why	The belt tracking device is not working.
Third Why	The belt tracker is tied off.
Fourth Why	The tracking device's pivot bearing is frozen and needs lubrication.
Fifth Why	The bearing could not be lubricated because the production schedule had eliminated time for maintenance.

Note that in this example the 'Fifth Why' suggests a broken process or a behavior that can be altered, which is indicative of reaching the root-cause level. One solution to the problem might be to install an automatic lubricator on the belt-tracking device.

In the example above, it is interesting to note that the last answer points to a process. This is one of the most important aspects in the '5 Whys' approach—the real root cause should point toward a process that is not working well or does not exist. Untrained facilitators will often observe that answers seem to point towards classical answers such as not enough time, not enough investment, or not enough manpower. While these answers may be true, they are beyond the control of the plant personnel and investigators. Therefore, at this point, it may be better to determine 'Why did the process fail?'

the interaction between management, labor, and machine.

Complex systems are not inherently safer than simple systems. In fact, many accidents happen with the system working as designed. The more complex and automated a system, the more likely an unexpected consequence will cause a production problem or an accident. Control algorithms are not perfect, and instruments often go out of calibration or fail. People often misunderstand visual, verbal, or written instructions and inadvertently contribute to a failure. Mixing electro-mechanical complexity with humans' freedom of choice and cognitive reasoning multiplies the opportunities for system problems or worker injury. The root causes of most equipment problems and accidents are a mixture of human behavior, technology, and management.

Because of the complexities, it is important to reconstruct the accident or anomaly and be careful not to jump to conclusions based on preconceived answers or inadequate sources of information, such as hindsight and hearsay.

One valuable approach is similar to the '5 Whys' technique, commonly used in continuous improvement programs, in that the real problem is often more than one 'Why' deep. (**See The '5 Whys' Technique.**)

Models for Accident Investigation

There are at least three mindsets for investigating an accident or malfunction. Often, one single model is not sufficient to construct the root cause(s) and identify remedies that would have a high chance of preventing future incidents.

The first is the ***sequence of events model.*** In the sequence of events model, a detailed time line is constructed including the critical events in the chain which, if removed, would have prevented the accident or failure. The sequence of events model is good for identifying cause and effect of simple technical or mechanical failures. The sequence of events model constructs a linear time line of the steps leading up to the event, but investigations using this method should avoid delving into constructing the reason 'why' people did what they did to contribute to the failure.

The second investigative model is the ***latent defect model*** which assumes that there could be an existing, but as yet undiscovered, defect in management policies and procedures, a software bug, or a hidden design problem. Any of these problems can lead to an accident when the combination of human and system interaction triggers a system failure. In the latent defect model the cause(s) are those issues that if they were modified, controlled, or removed, the accident would not have happened. This model is useful in exposing hidden faults and the effects of management style or corporate culture. The latent defect model helps the investigator to see the complex and sometimes subliminal organizational issues that 'trigger' the event. Even though this model may point to complex interactions between systems or between management and labor, it is often hard, because of complexities, to prove that a software bug or a management directive was a root cause.

The third approach is the ***systemic model***. This investigative approach looks at how resource constraints or imperfect knowledge of how the system interacts as possible root causes. Many accidents happen when the system is working normally but limits to factors such as time, production goals, or budgets cause people to push the system beyond its limits or in ways it was not designed to handle. This model is helpful in understanding why the workers made the decision(s) that preceded the event. This approach also looks at the complete picture of management, technology, and labor and reaches into all contributors to the event. An investigator using this method often runs into passive resistance from the various stakeholders involved in the chain of supply, installation, operation, and maintenance.

Which model an investigator chooses can determine the finding of the root cause. The sequence of events model makes it easy to conclude that if the worker had not taken certain actions, the accident would not have happened, and therefore, the unsafe act of the worker was the sole cause of the accident. The latent defect model makes it easy to pin the cause on technology and find the programmer, supplier, or engineer responsible in whole or in part. However, the systemic model is the most difficult to apply because there may be resistance to findings that are not simple answers but related to the complex interaction between man and machine. The systemic method is most useful for identifying deficiencies in the management system. Because of the natural resistance to find management as the problem, the systematic method is best conducted by third-party investigators whose goal is not to exonerate management but to get at the root cause.

In most cases, there will be multiple root causes involving the worker, the equipment, and the company culture. In some cases, it may not be possible to positively reach a conclusion as to the root cause(s).

Sequence of Events Root Cause Analysis

The sequence of events model is useful in identifying equipment problems that either have caused or are likely to cause a production outage or personal injury. Because many of the problems facing conveyors are mechanical or electrical in nature and specific to a particular conveyor, the sequence of events model will be used frequently to uncover and rectify root causes of conveyor malfunctions.

Figure 29.4.

A good investigative team is made up of workers familiar with the equipment, others who know general plant processes, and sometimes, outside consultants.

Procedure

1. Identify the problem to be addressed and the limits of the investigation by establishing when the time line is to begin and the specific equipment involved.
2. Gather available production data and maintenance records.
3. Construct the chain of events in a detailed time line that led to the pending or actual failure.
4. Identify the individual steps or actions (causes) that would have prevented the pending or actual failure.
5. List the causes in order of priority of contribution to the incident.
6. Document the definition of the problem, any assumptions made, the findings, and recommendations for addressing and prioritizing the procedures that would have the greatest effect on preventing future failures. Explain why the recommendations will solve or reduce the problem.
7. Implement immediately any simple and low-cost problem resolutions, such as change the automatic lubricator every four months instead of every six months.
8. Provide to management any recommendations that involve significant effort or expense for consideration.

A team approach utilizing people familiar with the specific equipment, the general plant processes, and outside expertise such as suppliers or consultants makes for a good mix of skills for the investigative team. (**Figure 29.4.**) Checklists such as inspection forms or equipment manuals are useful in the sequence of events model. If operating data or maintenance records are available, these documents can be useful in reconstructing the sequence of events and pointing to possible solutions.

After finding the cause(s), politics and practical limitations may make remediation of the problem difficult. Responses to findings are often met with 'if they just did the preventative maintenance,' or 'we cannot shut down to fix it,' or 'we do not have the budget or manpower

4

to fix it.' There are many examples of small problems becoming major failures and large-scale catastrophes. The most safety-conscious organizations realize that when equipment failures are quickly identified and corrected, production and safety both win. Many solutions can be considered part of a normal continuous improvement program and implemented to prevent future outages.

Latent Defect Root Cause Analysis

Latent defects can lie dormant for long periods of time before a particular chain of minor or unnoticeable events converge—often involving a combination of human error, system peculiarities, and corporate culture. The result is an otherwise undetectable incident. Latent defects often lay dormant because they are not easily uncovered by standard tests, inspections, or by meeting the minimum regulatory requirements. Normal wear and tear, in itself, is not a latent defect but can expose a latent defect if recommended maintenance has not been performed as specified. A latent defect might never surface or cause an accident.

The easy approach is to identify a design defect, a software glitch, or an unsafe act as the trigger

Latent Defect Cause Analysis: Buying on Price Turns 'As Equal' Specification into Equipment Failures

At a power plant in Southeast Asia, a company's procurement culture was conditioned to 'purchase on price.'

The plant's operations department wished to reduce belt damage and improve conveyor performance by installing impact cradles under the plant's belt conveyor loading zones.

The purchasing department included an 'or equal' line in the specification for the equipment required for this installation.

As a result, a total of eight cradles from an alternate supplier **(Figure 1)** were accepted as 'or equal' and purchased because they were lower in price. But under the stress of the application, these 'or equal' cradles failed within a month.

They were replaced with MARTIN® Impact Cradles **(Figure 2)** which had been the basis of the original specification. The replacement cradles lasted significantly longer and are still in service.

So by 'buying on price' without regard for the lifecycle cost of the equipment, the plant spent at least 1.5 times—and more likely 1.9 times the cost of the originally specified 'higher priced' product. The plant also suffered the increased downtime required for a second installation outage, and lost revenues as a result of the production missed during the second outage. In addition, plant workers risked injury working on or around conveyors with failing components.

Figure 1. *Purchased on Price and failed in one month.*

Figure 2. *Replaced with product originally specified.*

4

for the accident. This approach concludes: if this one act were prevented or eliminated, the accident would not have happened. However, many latent defects have their roots deeper within the organizational culture and structure.

Latent defects are often an underlying theory of liability in lawsuits. A latent defect is one that is hidden and that a skilled person would not reasonably be expected to detect under normal inspection procedures. On the other hand, patent defects are those that are obvious and should be detected by a skilled person under normal circumstances. Hindsight is often applied to determine that the design or product had a latent defect—now that it has become obvious to all concerned—and the designer or manufacturer should have known of the defect and has thus provided defective designs or products. Therefore, the steps taken in a latent defect investigation are often designed to benefit the plaintiff's claims and not for the purpose of improving safety.

The latent defect approach is effective in finding defective designs, incorrect installation, poor maintenance, and bad management decisions.

Searching for latent defects can help identify deficiencies in the interactions between humans and machines and start to explain the complex organizational issues that contributed to the accident. The recommended approach is to construct the chain of decisions and events that led to the latent defect causing an accident and then propose solutions.

Procedure

1. Describe the normal expected operation of the failed equipment or system.
2. Gather all policies and procedures (written or verbal) that relate to the events

Systemic Cause Analysis: Disabled Plug Detector Allows Chute Blockage to Create Safety Problems

In this plant, shortcuts allowed a disabled sensor to create a hazardous work condition.

On this conveyor, a plugged chute detector was disabled, and a chute blockage was cleared just enough to allow production to resume. Or perhaps a signal was ignored, and the conveyor remained in operation. As a result, there was spillage of the cargo and an overflow of large rocks accumulated on the walkway platform at the discharge pulley of the conveyor pulley.

These large rocks formed an unstable condition that poses a safety hazard. The rocks could fall from the platform onto workers or equipment below. Workers who need to walk or stand on the platform are at risk of a slip/trip/fall incident. Access to the belt cleaner inside the chute is made unsafe by the pile of rocks on the work platform. The openings in the chute offer potential exposure for a worker to the likelihood of falling and coming in contact with flowing material or the belt.

The work platform—normally designed for a load up to one ton per square meter—is clearly overloaded and could fail, further risking workers on or below the platform.

The case illustrates a plant culture and management style focused exclusively on production, with the result being a poor safety culture. A worker injury might be the result.

A disabled plugged chute detector results in the accumulation of materials on the walkway and the increased risk of worker accidents.

4

leading up to the failure. Include documentation such as manuals, drawings, and specifications.

3. Construct a detailed time line of events in the immediate past leading up to the failure. This can vary from a few minutes to a few days depending on how frequently and dramatically the process changes.
4. Identify the effect(s) of the failure(s).
5. Determine the root causes(s) of the failure(s).
6. Review current practices and controls.
7. Document the findings and recommendations.

To develop a detailed procedure, a useful document is *MIL-STD-1629A Procedures for Performing a Failure Mode, Effects and Criticality Analysis*. It is available for free download, as is the similarly useful *AMSAA Design for Reliability Handbook*, produced by the Material Systems Analysis Activity of the United States Army.

Systemic Root Cause Analysis

Systemic accident root causes are those that find their origins in failures of management controls that lead workers to make decisions that result in unsafe behavior. In the systemic investigative model, the conclusion could be that the workers tried to follow all the rules, but when faced with conflicting directives made reasonable decisions based on their understanding of the circumstances and the constraints of policy and procedure.

The systemic approach often finds that the accident was a normal and predictable outcome of policy and procedure, and that there was no equipment malfunction. Accidents that evolve in this manner are often difficult to investigate because of the complexity of the interactions of the management, worker, and machine.

CLOSING THOUGHTS

It can be considered that a good thing—the only good thing—to stem from an accident is the opportunity, the challenge, and the requirement to investigate root causes in order to prevent future incidents. By following the procedures outlined above, industrial operations can provide safer conditions and demonstrate continuous improvement. ⚠

4

Chapter 30 Job Hazard Analysis

4

INTRODUCTION

A Job Hazard Analysis is a risk assessment focused on specific definable tasks. A Job Hazard Analysis can have many different names such as task hazard analysis, job safety analysis, or even pre-job planning. Often within a company or an industry, initialisms such as JHA or JSA are used.

For conveyors, Job Hazard Analyses are most commonly associated with the performance of maintenance and repair activities, but they can (and should) be applied to all aspects of operating, maintaining, and cleaning the material-handling systems.

A Rose by Any Other Name

In a 2014 article, "JHA and JSA: the Same Thing? Different? Does it Matter?" presented on *EHSToday.com*, Jeff Dalto wrote:

> Some believe they're the exact same thing. Others think they're step 1 and step 2 of the same process. And still oth-

ers think they're similar processes that happen at a 'macro' and 'micro' level.

From the perspective of this volume, it does not make much difference what it is called, as long as it is done properly. It should be done carefully, step by step, at the level of the job where the worker interfaces with the task and the equipment, and the industrial environment.

Detective Work

As the United States Occupational Safety and Health Administration (OSHA) noted, in its publication *Job Hazard Analysis* (OSHA 3071-2002), "A job hazard analysis is an exercise in detective work."

The task of a job safety analysis is working out what could go wrong, mitigating those issues, and planning the work procedures—and the necessary tools and materials—in advance of starting the work. The assessments should take into account the work location and environmental conditions.

OSHA's *Job Hazard Analysis* publication sums it up:

> A job hazard analysis is a technique that focuses on job tasks as a way to identify hazards before they occur. It focuses on the relationship between the worker, the task, the tools, and the work environment. Ideally after you identify uncontrolled hazards, you will take steps to eliminate or reduce them to an acceptable risk level.

In the article cited above, Jeff Dalto listed the steps in a JHA/JSA as:

1. Breaking a job down into the smaller tasks that make up the job.
2. Identifying hazards associated with each task.
3. Ranking the hazards in order of the ones that must be addressed first to ones that can be addressed later (or maybe even not at all).
4. Designing and implementing controls for the hazards.

Step by Step

Nearly every job can be broken down into job tasks or steps. When beginning a Job Hazard Analysis, the recommended procedure is to watch the employee perform the job and list each step. Enough information should be recorded to describe each job action without being overly detailed. The breakdown of steps should not be so detailed that it becomes unnecessarily long or so broad that it does not include basic steps. It may be valuable to get input from other workers who have performed the same job.

Later, review the job steps with the worker to make sure no steps or procedures were omitted.

It may be beneficial to point out that the evaluation is of the task itself, rather than the employee's job performance. It is important to include the worker in all phases of the analysis—from reviewing the job steps and procedures, to discussing any uncontrolled hazards discovered, and the possible solutions.

Designing and Using the JHA Form

A way to move toward consistent completion of a Job Hazard Analysis for each task is the development of a JHA form. This form will both guide the reviewer through the process and provide a method to record the information. It is important to break down the job into individual steps and use the form to assess the hazards/risk in each step on each separate form.

It is good practice to avoid check-the-box forms. While a pre-job checklist can be a good thing, it is only as good as the person completing it. It is best to avoid forms where checking the box is all that is required. Human nature allows a worker to become familiar with the form, and then casually and cursorily check the boxes in a manner that will satisfy the requirement, if not the intent.

If checklists are used, it is best to make several versions available or to scramble the order of the questions. It is better to construct the form in such a way that it requires a short written answer.

Figure 30.1.

Sample blank Job Hazard Analysis form, as presented in U.S. OSHA Publication 3071, Appendix 3.

Example's of Job Hazard Analysis Forms

Job Title:	**Job Location:**	**Analyst:**	**Date:**
Task#	*Task Description:*		
Hazard Type	*Hazard Description:*		
Consequence	*Hazard Controls:*		
Rationale or Comment:			

Courtesy of the Occupational Health and Safety Administration, United States Department of Labor.

Figure 30.2.

Example of a completed Job Hazard Analysis Form, as presented in U.S. OSHA Publication 3071.

Job Location: *Metal Shop*	**Analyst:** *Joe Safety*	**Date:**
Task Description: Worker reaches into a metal box to right of machine, grasps a 15-pound casting and carries it to grinding wheel. Worker grinds 20 to 30 castings per hour.		
Hazard Description: Picking up a casting, the employee could drop it onto his foot. The casting's weight and height could seriously injure the worker's foot or toes.		
Hazard Controls: 1. Remove castings from the box and place them on a table next to the grinder. 2. Wear Steel-toe shoes with arch protection. 3. Change protective gloves that allow a better grip. 4. Use a device to pick up castings.		

Courtesy of the Occupational Health and Safety Administration, United States Department of Labor.

Samples of blank and completed forms as developed by OSHA in the United States are shown in **Figure 30.1** and **Figure 30.2**.

BEST PRACTICES Performing a Job Hazard Analysis

1. Involve the workers who will—or have performed—the activity. It is helpful to include personnel in the discussion who are from other crafts or disciplines.
2. Define the job to be done. If it is a complex project or extends over a protracted period of time with different workers at different times, break down the job into sub-tasks.
3. Discuss with the group the known hazards and issues within the context of the location, the tools, and work to be performed. It is important to include known past injuries or near misses, and to brainstorm what other hazards and risky activities may occur:
   - What can go wrong?
   - What are the consequences?
   - How could it arise?
   - What are other contributing factors?
   - How likely is it that the hazard will occur?
   - Where it is happening (environment)?
   - Who or what it is happening to (exposure)?
   - What precipitates the hazard (trigger)?
   - What outcome would occur should it happen?
   - What are other contributing factors?
4. List each of the main hazards and/or risky activities.

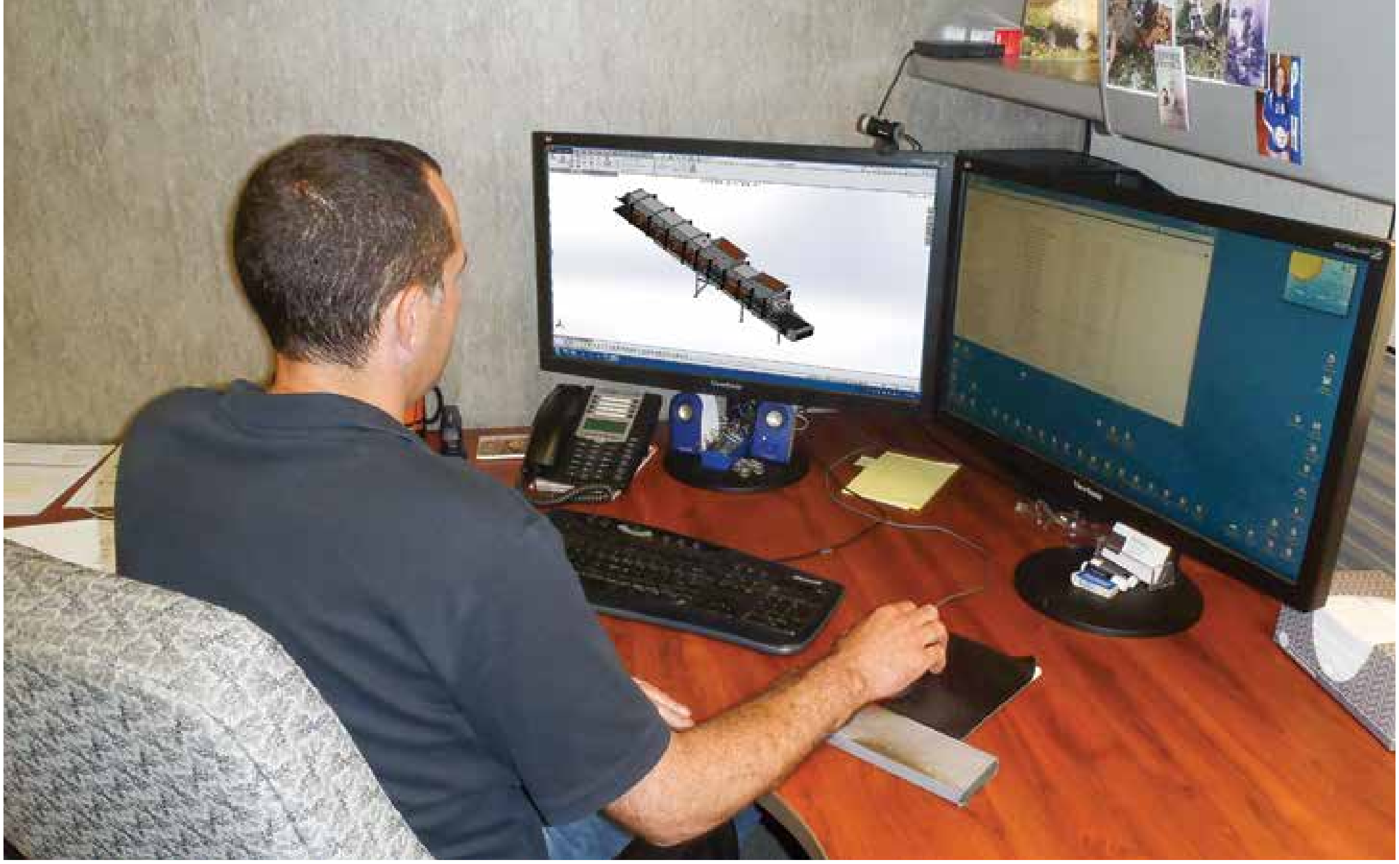
5. Develop a plan to reduce the exposure to hazards and minimize risky activities.
6. Document the Job Safety Analysis for each step necessary to complete the task. Most companies will have a standard format to use for this purpose. Describing a hazard in a standardized format helps to ensure that efforts to eliminate the hazard and implement hazard controls help target the most important contributors to the hazard. There are numerous software applications to assist in a complete job analysis and documentation.

CLOSING THOUGHTS

The United States OSHA publication, *Job Hazard Analysis*, emphasizes the importance of conducting Job Hazard Analysis, noting:

> For a job hazard analysis to be effective, management must demonstrate its commitment to safety and health and follow through to correct any uncontrolled hazards identified. Otherwise, management will lose credibility and employees may hesitate to go to management when dangerous conditions threaten them. ⚠

Section 5 BUILDING BETTER, SAFER CONVEYORS



Chapter 31 Designing and Building Safer Conveyors

INTRODUCTION

Issues in Conveyor Design

Safety is like bulk-materials handling—part science and part art. It is much easier to apply an engineering formula to determine the tension required at the drive pulley than it is to predict the frequency and severity of accidents. It is just as hard to predict the tracking of a conveyor belt as it is to predict the frequency and severity of accidents; there are just too many variables to make it a pure science.

It seems common sense (and good engineering) to modify the basic approach to conveyor design and procurement practices which have basically gone unchanged for over a century. This common sense approach will allow the conveyor(s) to provide improved performance in bulk-materials handling and in worker safety.

Safety professionals still struggle with providing direct evidence regarding the influence and value of design on safety. Part of the reason for the difficulty of providing a universal relationship may be that there seems to be an endless number of ways that workers get injured and putting them into neat categories is difficult. Another factor is that financial analysis is best suited to quantifying direct costs, while accounting for safety often involves a more qualitative approach to determine less tangible costs. While standard accounting relies on countless estimates and judgments, accountants have not agreed upon a methodology to apply to less tangible cost estimates.

There are a variety of methods employed to reduce hazards in the workplace. They can be arranged in a hierarchy of tactics which provides a method to improve safety and reduce risk. These are arranged in a hierarchy of control levels. All of the tactics for alleviating hazards are important to overall safety. Some are more effective than others for a variety of reasons and at a range of levels. But, there is consensus among safety professionals that the most effective way to mitigate risks is to design the hazard out of the product or system.

A Hierarchy for Hazard Reduction

These tactics or methods—in order of increasing effectiveness—include Personal Protective Equipment (PPE), Administrative Controls, Engineering Controls, Substitution, and finally, Hazard Elimination by Design. (**Figure 31.1.**) This 'Hierarchy of Controls' should be considered when implementing controls to eliminate or reduce the risk of a hazard. Generally speaking, the higher up the list of the hierarchy, the safer workers are.

The hierarchy of hazard control emphasizes controlling a hazard at the source. This is done by giving preference to the use of design approaches. These types of strategies should be used, where possible, because they are less subject to human failure and because they are less disruptive and uncomfortable for people working in the area. The lower ranked controls—such as PPE and Administrative Controls—are necessary but should not be relied upon solely, but rather used to support other control measures. In many cases, it will be necessary to use more than one control method.

Whichever tactics are used, regular monitoring is important to make sure that the hazard control is working effectively and that exposure to the hazard is reduced or eliminated.

All of the tactics for alleviating hazards offer some improvements for overall safety. They each offer some advantages and some disadvantages; the following is an overview.

PPE

Personal Protective Equipment (PPE) provides a barrier between the wearer and the hazard. Personal protective equipment includes respirators, safety goggles, blast shields, hard hats, hearing protectors, gloves, face shields, and footwear.

PPE can be effective in reducing exposure to hazards and reducing injuries and even death. However, the use of PPE does not change the intensity or nature of the hazards; they simply guard against the hazards.

PPE is the least effective means of control because it does not eliminate the hazard but may only limit the potential for worker injury. Enforcing the use of PPE is problematic because it sometimes contributes to less-than-desirable conditions, such as safety glasses that are difficult to see through or a fall-protection harness that cuts off circulation when the worker is suspended. Therefore, PPE is often viewed by workers as creating a more dangerous situation than the injury being

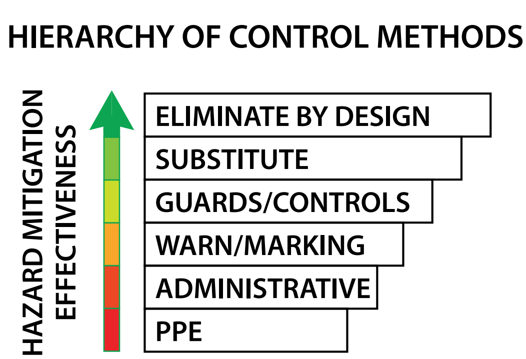


Figure 31.1.

As the type of hazard control moves higher up the hierarchy of methods, the safer workers are.

5

protected against. Additionally, some PPE, such as respirators, increases the physiological effort required to complete a task, and therefore, may require medical examinations to ensure the PPE can be used without risking worker health.

Administrative Controls

Administrative Controls represent changes to the way people work. Administrative Controls do not remove hazards but limit or prevent a worker's exposure to the hazards. Examples include establishing policies and procedures to minimize the risks, scheduling jobs to limit exposure, posting hazard signs, restricting access, and requiring training for personnel.

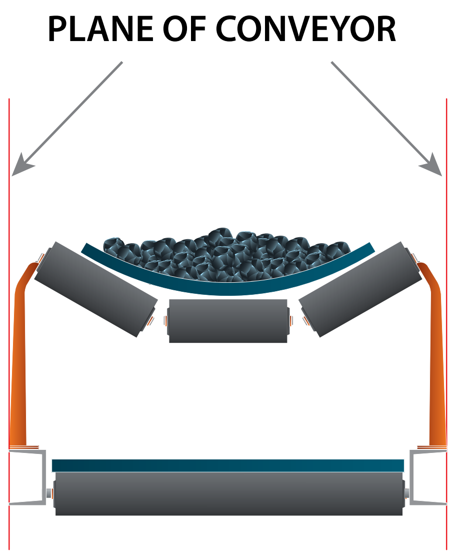


Figure 31.2.

Theoretical Safety Plane at Stringer.

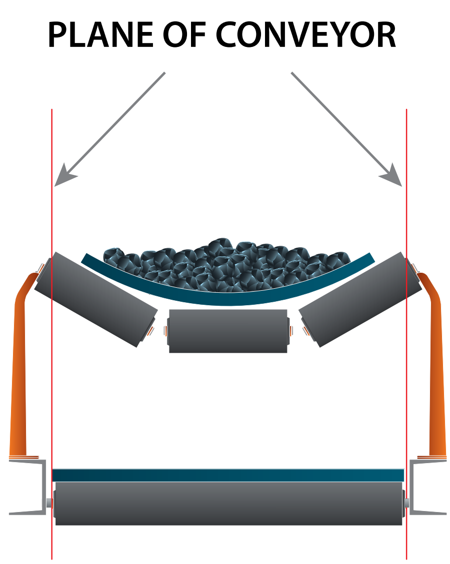


Figure 31.3.

Theoretical Safety Plane at Width of Return Belt.

Administrative Controls can be thought of as 'Safety by Edict: Thou shalt do it this way; Thou shall not do that.' If 'Safety by Edict' was effective then there would never be any worker hurt by a moving conveyor as virtually all plants and mines have rules against working on a moving conveyor.

Administrative policies are difficult to develop into concise and universal rules so that workers at all levels can comprehend, apply, and strictly follow them.

Administrative rules, and the consequences for breaking them, have to be interpreted in the context of the management's safety attitude. In operations with less than a 100 percent management dedication to safety, safety policy and procedures may be skirted to keep production going or because there are few consequences for breaking the rules.

In the case of conveyors, Administrative Controls rules can be summarized as 'Don't Break the Plane of the Conveyor.' The plane is an invisible line of demarcation that a worker is not supposed to cross. Just where this invisible barrier is established is different from one operation to the next. Some consider the outer surface of the conveyor stringers mark the plane. (**Figure 31.2.**) Others consider the edge of the belt to mark the plane. (**Figure 31.3.**) Either way, an invisible plane is hardly a guarantee that workers will not reach inside.

Engineering Controls

A somewhat more effective means of controlling hazards is Engineering Controls. These do not eliminate hazards, but rather isolate people from hazards. 'Enclosure and isolation' creates a physical barrier between personnel and hazards, such as using remotely controlled equipment.

Guards, installed to protect a specific hazard or an area, are on the list of Engineering Controls. (**See Chapter 10 Guarding**.) However, the Mine Safety and Health Administration (MSHA) has reported that guards cause a significant number of injuries every year due to the poor design of the guard. These injuries are primarily from guards that are too heavy, inherently dangerous—with sharp edges, for example—or improperly sized or positioned.

There is debate on the effectiveness of area guarding. Some feel the use of area guards means hazards inside the guarded area may not be sufficiently guarded and so the area guards can offer a false sense of security. Others find properly installed and properly managed area guards are effective and useful.

A trend in belt conveyor safety is to guard the entire conveyor with physical barrier guards. This can be quite expensive and is impractical with very long conveyors, such as overland conveyors.

Another current trend in safety is that the guards are being interlocked to the conveyor drive. This will prevent operators and maintenance personnel from leaving the guards off of equipment. Unfortunately, many such interlocks are bypassed because operators and maintenance personnel view the interlocks as a hindrance to their procedures, or the interlocks cause false 'trips' of the conveyor circuit. Interlocking hundreds of guard panels is also impractical and may create more hazards than it protects.

In the United States, the National Institute for Occupational Safety and Health (NIOSH) is investigating the use of interlocks in combination with proximity switches to detect if workers have not replaced the guard at an appropriate time after removing it.

A more advanced form of engineering controls is guarding using devices such as light curtains or proximity sensors. In the United States, MSHA has been working on using proximity sensors to reduce crushing injuries around continuous miners.

It is suggested that a sensible balance be adopted between using interlocking guards in the zones with a high risk for accidents and using non-interlocking guards in lower risk areas, rather than interlocking all the guards particularly on longer conveyors. Generally, the high accident zones will be those around the head, tail, and takeup areas of the conveyor—the locations where the most frequent cleaning and maintenance activities take place.

The capital costs for Engineered Controls tend to be higher than the less effective controls in the hierarchy. However, a wise investment in engineered controls may reduce future costs. For example, a crew might build a work platform rather than purchase, replace, and maintain fall-arrest equipment.

Substitution

Substitution is considered one of the more effective control methods. Substitution involves replacing something that produces a hazard—be it a situation, a material, or a piece of equipment—with something that does not produce a hazard. A substance determined carcinogenic could be replaced with another, less risky substance. For example, lead-based paint could be replaced with a water-based paint or powder coating.

To be an effective control, the Substitution must not produce another significant hazard. It is important to assess what new risks the substitute may pose.

However, Substitution is often not an option for belt conveyor systems. In some cases, there may be alternative conveyance methods, usually for lower tonnages, but it may be difficult or impossible to achieve the same volume of throughput when replacing a belt conveyor with another method—such as an enclosed pneumatic conveyor. When the cargo being carried is in itself a hazard, there are a number of enclosed conveyor systems available—such as pipe or folding conveyors—that will reduce the probability of the cargo being released into the air. Air-supported conveyors reduce the number of nip points by eliminating most of the idlers in a system and are often fully enclosed to reduce contamination issues. (**Figure 31.4.**)

Substitution can be a useful strategy when applied to components or maintenance supplies. For example, if the safety issue is noise, quieter components can be substituted. If a cleaning method uses hazardous chemicals, a safer chemical could be substituted or the procedure modified to reduce exposure.

However, Substitution can create significant problems. If the original conveyor design is not suitable for a wide range of bulk-material properties, or the system is designed without room for upgrades, one change may create other problems. For example, substituting lubricants without researching compatibility can reduce bearing life. When lower-quality bulk materials are run in the system, problems such as plugged chutes, quality issues, increased component wear, and the escape of fugitive material are common.

When making Substitution decisions, it is important to be cautious of the unintended or underestimated effects of the change on the conveyor system and process.

Hazard Elimination

Eliminating the hazard—physically removing or relocating it—is the most effective method of hazard control. For example, if employees must work high above the ground, the falling-from-heights hazard can be managed by moving the piece they are working on to ground level.

The most effective way to control a hazard is to eliminate it in the design stage. Legislation in many countries places a legal responsibility upon designers to consider the life of a project and to eliminate, through design, specific hazards and risks. There are many simple design approaches that can reduce or even eliminate hazards common with conveyors.

Figure 31.4.

Because air-supported conveyors reduce the number of nip points and are often fully enclosed to reduce contamination issues, they represent an effective substitution for conventional belt conveyors.

These approaches are known under various names, such as Safety by Design, Safe Design, or Design for Safety.

Safety by Design is an iterative approach to design using hazard identification and risk-assessment methods early in the design process to eliminate or minimize the risks of injury over the life cycle of the conveyor system. Effective Safety by Design encompasses all of the design disciplines involved in a project. In applying Safety by Design to conveyors, the focus in this book is on designs that reduce accidents, reduce the escape of fugitive materials, and improve maintenance effectiveness to provide **Production Done Safely™**.

Implementing Safety by Design is much more cost-effective than when the hazards become real risks to clients, users, employees, and businesses. The direct costs associated with unsafe design can be significant, such as retrofitting, increased insurance costs, environmental damage, product loss, and negligence claims. **Chapter 33 Accounting for Safety** and **Chapter 34 The Payback for Safety** explore how to measure and consider indirect costs in the evaluation of design and component selection.

Specification writers should realize the effectiveness of this technique and avoid writing bid documents that are so restrictive or specific that designing the hazard out of the equipment or process is not possible without taking exception to the specification.

Prevention through Design (PtD)

In the United States, NIOSH is leading a national initiative to promote PtD. The NIOSH publication, *Prevention through Design: Plan for the National Initiative*, identifies the initiative's mission as:

> ... To prevent or reduce occupationally related injuries, illnesses, fatalities, and exposures by including prevention considerations in all designs that affect individuals in the occupational environment.

5

This will be accomplished through the application of hazard elimination and risk minimization methods in the design of work facilities, processes, equipment, tools, work methods, and work organization.

When embraced by owners and managers, PtD is an opportunity for designers to create new and practical design solutions. The benefits of PtD extend beyond the design phase of a project. These benefits include:

- Reduced injury and industrial disease
- Improved conveyor availability and productivity
- Reduced operating and maintenance costs
- Reduced fines and legal costs by exceeding compliance standards
- Improved ability to incorporate future upgrades

The ability to incorporate risk-reducing techniques is greatest when a project is in the specification and design stages, rather than later in its construction. **Figure 31.5** compares the relative ability to implement effective hazard control techniques at various stages of a project. This 'ability to implement' can be translated into the very comparable 'cost to implement,' with changes that occur later in the project incurring a significantly higher cost for the improvement.

The cost to implement safety improvements during construction can be from three to five times as much as when the improvement is incorporated in the design stage. Efforts to retroactively implement improvements during the Start-up and Operation phases can cost 15 to 100 times as much, if improvements are even possible due to designed-in restrictions.

It seems intuitive that mitigating hazards as early in a project as possible would result in the lowest incident rate and have a payback that justifies the expenses incurred.

A Brief History of Conveyor Design

The book, *Belt Conveyors and Belt Elevators*, published in 1922 by Frederic V. Hetzel provides the first well-documented history of the development of belt conveyors for bulk materials. This work describes the earliest use of belt conveyors for handling grain in England and the United Sates around 1795. By 1860, grain conveyors of various designs were traveling at 650 feet per minute [≈3.3 m/sec] and handling 12,000 bushels [≈325 MT] of grain per hour.

By 1860, belt conveyors were reported handling other materials such as coal and iron ore. The New Jersey and Pennsylvania Concentrating Plant in Edison, New Jersey, had 50 belts up to 30 inches [≈760 mm] wide and 500 feet [≈150 m] long to handle iron ore. Beginning in 1891, Thomas Robbins began introducing improvements in idler design and belt construction at the New Jersey and Pennsylvania Concentrating Plant. By 1910, Robbins' designs had reached the state where they would still be recognized today as contemporary belt conveyor components and construction.

It is often stated that insanity is doing the same thing over and over again and expecting different results. Sadly, that is the state of belt conveyor design today, using 100-year-old design concepts while expecting clean, safe, and productive conveyor systems.

The Problems with 'Low Bid' Procurement

Many companies still utilize a 'Low Bid' Process for procurement. In this process, the contract is

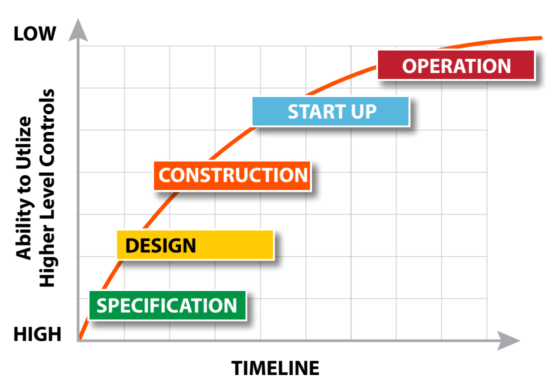


Figure 31.5.

Incorporation of effective hazard control techniques is easier and less costly in the early stages of a project.

5

awarded to the lowest price of several bidders' proposals that meet project specifications.

The Low Bid Process forces bidders to follow a belt conveyor design methodology that is based on:

1. Maximum loading on the conveyor belt.
2. Minimum compliance with regulations.
3. Lowest price materials, components, and manufacturing processes.

While a direct correlation between increased accidents and higher operating costs when following low-bid design and construction hierarchy is difficult to establish, it is the author's contention that many safety professionals would agree with this bold statement: 'The Low Bid Process Kills People.' At a minimum, they would agree with 'The Low Bid Process is problematic when it comes to safety.'

To maximize the tons per hour while minimizing the price of the system, the combination selected is usually the narrowest belt possible operating at the highest speed possible. Usually, the system will be designed so the belt is loaded at or beyond full capacity with a minimum edge distance. These design choices result in a variety of problems including spillage, chute plugging, and increased wear. As a result of these choices, finished systems rarely deliver the specified design capacity.

Specifications for project components often state 'Specific Manufacturer Name'/ Or Equal.' These 'Or Equal' specifications are often vaguely written due to time constraints or competitive reasons. This deliberately encourages purchase from a preferred supplier while creating the façade of obtaining several competitive bids. The courts have consistently ruled that a component is a component in an 'Or Equal' specification, regardless of whether or not it is actually equal in construction or performance. This methodology allows the purchasing department to purchase on price without adequate consideration for construction or performance. Purchasing departments are often tasked and sometimes incentivized to reduce purchase prices. A better approach for safety, cleanliness, and productivity would be to require purchasing based on life cycle cost, rather than initial purchase price.

In the Low Bid Process, compliance with regulations is treated as a minimum threshold to be achieved in order to reduce costs. Many regulations are non-specific and have no process for the manufacturer to certify to the purchaser that the design meets or exceeds the requirements. This leaves room for minimal compliance even though most likely the customer and the designer may be aware of improved practices, materials, and techniques.

Enforcement of regulations is often subjective based on a particular inspector's interpretation. This practice results in a conveyor with less than state-of-the-art design details for safety and health-related systems. This leaves the customer open to citations even with a brand-new conveyor. These can also lead to costly liability issues, as juries have consistently rejected a 'minimum compliance' defense in lawsuits, instead relying on current best practices to determine verdicts.

As noted by Kenneth Ross in an article, "Compliance with Product Safety Standards as a Defense to Product Liability Litigation," published in October 2010 in *In Compliance* magazine:

> … Compliance with all applicable laws and regulations is not, for most products, an absolute defense in a product liability case. Therefore, a jury could come back and say a manufacturer should have exceeded laws and regulations pertaining to safety.

Another problem arises in that, to be competitive, a bidder in the Low Bid Process will often minimize design time by using past designs and standardized details. Because the bid process is price-driven, rather than performance- or life cycle cost-driven, the designers' time in the field to observe and improve prior designs is limited or non-existent. This results in the mistakes of the past being repeated and opportunities for improvement being overlooked.

Consequently, the conventional Low Bid Process often results in cutting corners which physically constricts the ability to effectively retrofit production- and safety-related improvements.

A Better Theory of Conveyor Design

Bulk-materials-handling conveyors are built much the same as they were 50 or even 100 years ago. The most often heard justification for building 'the same' conveyors—with the same design and the same problems—is the need to stay competitive in system cost. Almost every other aspect of conveying, the materials of construction, and the expectations of management and the workers have changed over the years.

There are many computer software programs that incorporate conveyor design standards. These design standards focus on calculating the belt tension and establishing the drive power at full capacity. Conventional software usually does not address how to lay out a belt conveyor to be safer, cleaner, and more productive. (**Figure 31.6.**)

The time has come for a new generation of belt conveyor design, built to comply with current regulatory standards, meet societal requirements and productivity expectations, and utilize modern fabrication techniques. This new design must be developed by questioning every step of the conventional conveyor engineering methodology. This new methodology can be developed by simply asking, 'Why is that system/subsystem/component designed in that fashion?' and 'Could it be done in different ways?' This new approach will reduce risk, improve safety, control fugitive material,

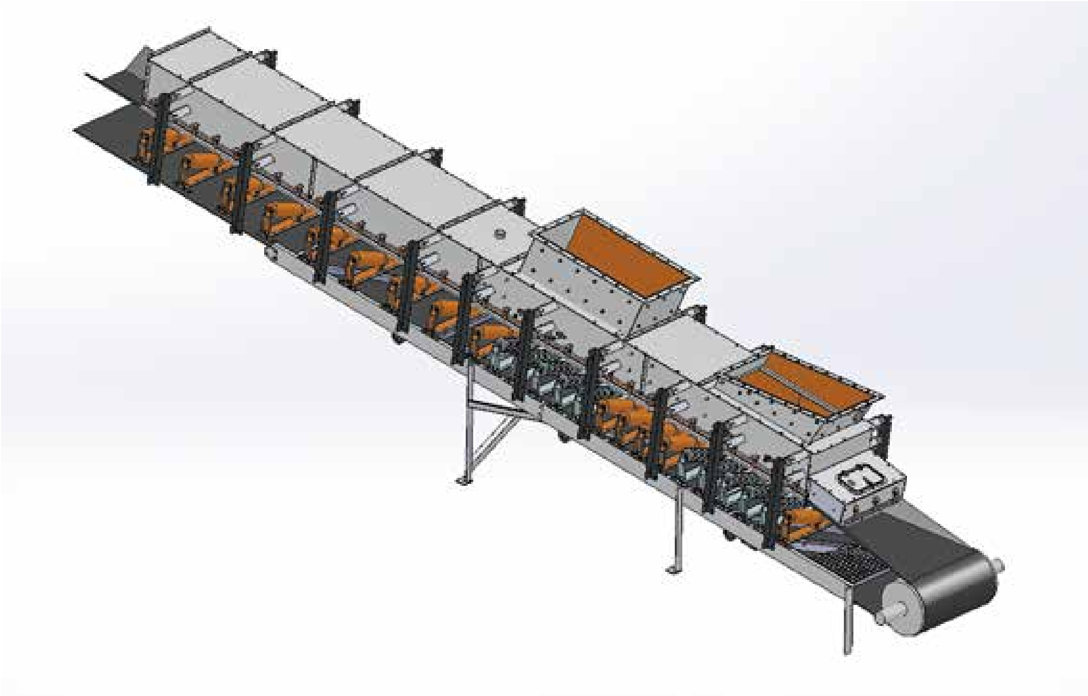


Figure 31.6.

While there are computer programs to help design conveyors, conventional software does not address how to make a belt conveyor safer, cleaner, and more productive.

and elevate productivity without significantly increasing cost or complicating maintenance.

This desire for a new generation of design has led to the development of a new approach to solving the common problems of belt conveyors. An advanced design hierarchy has developed which prioritizes design process decisions in order of importance when specifying and designing a clean, safe, and productive conveyor.

A Design Hierarchy, Evolved

The commitments for a conveyor system that is engineered to be safe, clean, and productive in order to provide **Production Done Safely™** are prioritized below:

1. *Throughput* – Throughput is the number one design criteria. The conveyor must safely and reliably deliver the design capacity.
2. *Safety* – The conveyor will exceed all code, safety, and regulatory requirements using global Best Practices.
3. *Cleanliness* – The design will minimize the escape and accumulation of fugitive materials.
4. *Service-Friendly* – The conveyor will be designed for ease of installation and maintenance.
5. *Cost-Effective* – The conveyor will use standard components in the basic configuration of the conveyor. The system will provide improved safety and access without increasing the structural steel requirements. Life cycle-costing will be used in making component decisions.
6. *Upgradeable* – Problem areas will be anticipated; space for retrofitted, problem-solving components when issues arise will be incorporated. The ability to accommodate future increases in capacity will be included in the original design.

Concept/Feasibility Study Checklist

The purpose of the following checklists is to highlight evolutionary details to consider and compare early in the design process for a bulk-materials-conveyor project. These details should help in the development of Safer, Cleaner, More Productive belt conveyor systems.

These lists are not intended to be all-encompassing, nor detailed enough to be used as a stand-alone template for a conceptual or feasibility study.

EVOLVED BASIC CONVEYOR

An Evolved Basic Conveyor is a standard bulk-material-handling conveyor that can be built competitively with a few modifications in critical areas. This design will allow the conveyor to be more easily retrofitted with components that solve common operation and maintenance problems.

An Evolved Basic Conveyor is designed with:

1. Conveyor Equipment Manufacturer Association (CEMA) recommended clearances for access.
2. Larger diameter terminal pulleys than the minimum based on belt rating.
3. Full trough transitions at the tail; belt is loaded only after being fully troughed.
4. Structural and design considerations for safety and cleaning in the load and discharge zones.
5. Adequate belt-cleaning provisions at the tail, takeup, intermediate drive, and discharge zones.
6. Anticipation of future upgrades in component ratings or serviceability and/or conveyor capacity.

Most other features of the Evolved Basic Conveyor are similar to a conventional 'Low Bid' conveyor. The Evolved Basic Conveyor fabrication can be designed to have a total steel

5

weight (and thus cost) at roughly the same as a comparable 'Low Bid' conveyor. Standard components can be used if the design allows for the future addition of problem-solving components and adequate access.

EVOLVED IMPROVED CONVEYOR

A Fully Evolved Improved Conveyor may never exist except on paper to show all of the possible enhancements to an Evolved Basic Conveyor. The intent here is to identify all the possible upgrades, in order to encourage the construction of Evolved Basic Conveyors. That way, the system can be more easily upgraded to solve typical problems as they occur in the operation and maintenance of belt conveyors. Because conveyor problems are difficult to predict before the conveyor is put in operation—due to the multitude of variables and design trade-offs in conveyor construction, installation, and operation—it is not necessary or economically feasible to include all Evolved Conveyor concepts in a single conveyor design.

Possible enhancements to an Evolved Basic Conveyor include:

1. *No Transition Idlers in Tail Zone.* Transition idlers are a wasted expense as 90 percent never touch the belt. In addition, the idler frames and conveyor structure combine to make it difficult to install and maintain a tail protection plow.
2. *Larger Terminal Pulleys.* Larger pulleys allow enough space between the upper and lower run of the belt for installation of a plow to protect the tail pulley. The pulley should have a minimum diameter of 600 millimeters [≈24 in.]. Using an oversize pulley allows for installation of a plow that can eject foreign objects without hitting the stringer. The added cost for a larger pulley is a few hundred dollars in most cases; this is saved by eliminating the need for transition idlers in the tail zone and increased splice life. A larger pulley at the discharge allows room for more than one belt cleaner. (**Figure 31.7.**)
3. *Problem-Solving Components Under the Load Zone.* Install engineered components to improve belt support while simplifying maintenance. These components include easy-maintenance slide-in/slide-out idlers, impact cradles, and seal-support cradles.
4. *Special Stringer in the Load Zone.* Use of a buildup-resistant structure in

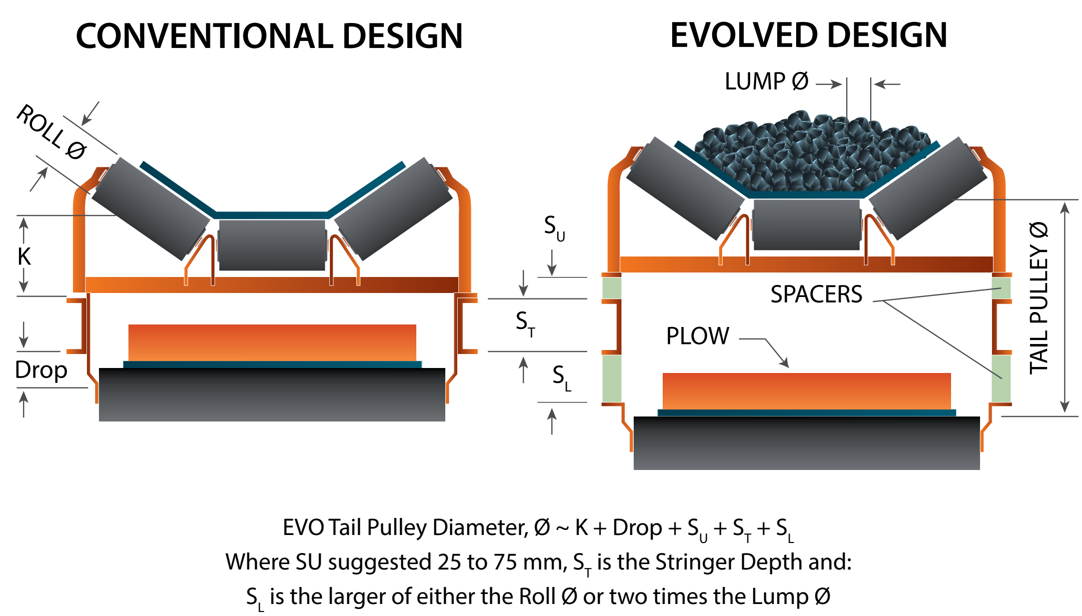


Figure 31.7.

Comparison of conveyor design alternatives to allow larger tail pulley diameter.

5

the load zone reduces accumulation of fugitive materials and, if pre-drilled with a standard hole pattern, assists in installation of problem-solving components without welding or cutting.

5. *Improved Head Pulley Supports.* The structure at the head pulley should be designed so that a cleaning station can be added using a scavenger conveyor—which allows off-pulley cleaners along the conveyor return—after the head pulley.
6. *Enlarged Skirtboard and Engineered Settling Zone.* These improved transfer-point components will allow dust to settle out of the air and reduce spillage.
7. *Belt Splicing and Repair Station.* A workspace for belt service will improve belt maintenance with reduced outage time.
8. *Elimination of Conduit in Critical Maintenance Areas.* At the Load Zone and Head Zone, re-route conduit overhead. Flexible conduit should be used to connect to the components in these zones.
9. *Takeup Guides.* Systems to assure even travel of the gravity takeup will promote consistent belt tracking.
10. *Curved Loading and Discharge Chutes.* These engineered systems are used to control cargo placement and reduce fugitive material.
11. *Flow Aids.* Installation of devices such as vibrators or air cannons on chutes will sustain material movement.
12. *Access to Utilities.* Adequate access to utilities including electricity and/or compressed air will allow for improved maintenance and better performance.
13. *Maintenance Aids.* The design should include equipment such as overhead monorails or jib cranes to assist in the movement and replacement of components.
14. *Motorized Head Pulley.* A motorized head pulley can improve access and improve sealing at the head chute, reducing the release of fugitive materials.

BEST PRACTICES
Red, Amber, Green Lists

The design process starts with the premise of **Production Done Safely™**.

Many of the Best Practices incorporated in a specification for a safe, clean, productive belt conveyor can be summarized in a Red, Amber, and Green list. Red means 'To Be Avoided.' Amber means 'Be Careful, Reduce, or Eliminate.' Green means 'Desired and/or Required.'

The following Red, Amber, and Green list offers practical guidance for designers on what to avoid and what to encourage in the specification and design phases of a conveyor project. (**Figure 31.8.**)

Retrofitting and/or Upgrading Conveyors

There are several reasons belt conveyors are used to transport bulk materials. Presumably, the cost per ton per unit distance is one of the main drivers.

In determining the ability of a conveyor to deliver a specific capacity, it seems initially obvious that the faster the belt travels and the more fully loaded the belt, the better the cost per ton per unit distance. However, the attempt to increase capacity by increasing conveyor speed is not without some serious drawbacks and in many cases actually results in lower output.

Changes in raw material quality lead many projects to increase capacity. Often, lower cost but harder-to-handle raw material are substituted in production processes. Often the physical properties of the substituted material are incompatible with the original conveyor design. Most of the time, the lower-cost materials require greater volumes to be conveyed. This is required to put the equivalent tonnage per hour into the process, because the lower-cost material has a lower bulk density, lower ore content, or lower energy content.

The common problems from upgrading capacity by increasing conveyor speed are increased wear resulting in increased maintenance time and cost, plugged chutes and spillage resulting in lower conveyor loading and increased cleaning costs. (**See Problems Seen When Upgrading Conveyor Capacity.**) Often the need for additional maintenance budget and hours is overlooked.

It can be argued there is almost a 100 percent certainty that most conveyor systems will require retrofitting with new technology or problem-solving components over their service life. Providing the ability to retrofit problem-solving components or new technology should be proactively considered in the design stage with minimal additional cost.

Upgrading to increase capacity is almost certain, but cannot be effectively considered in the design stage without the owner making the possibility known in the specification stage.

Red, Amber, and Green List for Designing Better Belt Conveyors	
RED LIst	*Procedures, techniques, products, and processes to be prohibited in the Specification and Design stages of a conveyor project.*
	Prevent loading on the transition of the belt.
	Prevent transition of more than 1/3 trough.
	Prevent loading against the direction of the receiving belt.
	Prevent loading conveyor to 100% of CEMA standard cross-section capacity.
	Prevent control and sequencing that allows conveyor(s) to run empty longer than necessary.
	Prevent belt identification stamps in top cover.
	Prevent installing equipment in elevated locations without provision of safe access or tie-offs.
	Prevent component selection based on 'Or Equal' specifications or 'Price Only' bidding.
AMBER LIST	*Procedures, techniques, products, and processes to be eliminated or reduced as much as reasonably possible. Only allowed with a change in the specification and notice to project owner/manager explaining potential issues and ability to address them in the future.*
	Avoid reversing conveyors.
	Avoid multiple load points on a single conveyor.
	Avoid designs created with the intention to increase capacity in the future by increasing conveyor speed; design the system to accommodate future needs.
	Avoid combined vehicle and personnel travelways or uncontrolled exits from buildings into traffic patterns.
	Avoid a site layout that does not allow for safe and efficient delivery, storage, and lifting of major components such as pulleys, drives, and belting.
GREEN LIST	*Procedures, techniques, products, and processes to be encouraged in specification and design stages of a conveyor project.*
	Consider ergonomics in the design and access of frequently cleaned or maintained equipment.
	Consider use of pulleys with diameters larger than minimum required for the specified belting.
	Consider access and clearances according to CEMA recommendations.
	Consider the use of design to reduce exposure to hazards.

Figure 31.8.

Red, Amber, and Green List for Designing Better Conveyors.

5

Considerations for future capacity upgrades can involve additional initial costs but often at a lower cost than trying to fit faster, wider conveyors into an existing space. Considerations for upgrading capacity at the design stage include: wider structural clearance, increasing design loads, changing idler trough angles, loading and discharge chute changes, drive requirements and belting.

CLOSING THOUGHTS
A Better Way to Design (and Buy) Conveyors

As discussed earlier in this chapter, the best—and certainly least expensive—way to solve these problems is in the design stage.

Engineering/Procurement/Construction Management (EPCM) services often represent some 10 to 15 percent of the installed cost of a major project at a bulk-materials-handling facility. Yet within these costs, design often

Problems Seen When Upgrading Conveyor Capacity

A number of problems are encountered when upgrading the capacity of existing conveyor systems. These unforeseen complications include:

Shorter Belt Life

Estimating belt life is based on a belt manufacturer's knowledge from actual case studies. Under one belting manufacturer's system, belt cover thickness is proportional to the Belt Speed times Application Factors divided by Belt Length. The Application Factors considered include material size and abrasiveness, feeding condition, belt speed, and transfer drop height.

In an application where conditions such as with material properties or belt speed change, the Application Factor changes an average of 175 percent. So with a 25 percent increase in belt speed, there is the potential for a reduction in belt life of approximately 50 percent.

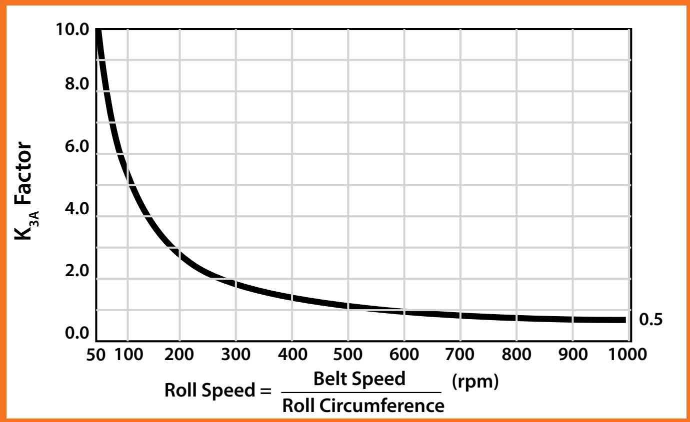
$$\frac{100\%}{1.25 \times 1.75} = \sim 46\%$$

As a result, the costs for more frequent belt replacement should be considered in the decision to increase conveyor capacity.

Shorter Idler Bearing Life

In discussing the life of idler bearings, CEMA's *Belt Conveyors for Bulk Materials, 7th Edition*, notes, "Slower speeds increase life and faster speeds decrease life." Using CEMA's K_{3A} factor (based on actual roll speed), a 25 percent increase in belt speed will translate into a 20 percent reduction in the L_{10} bearing life of a typical idler.

(L_{10} is a failure rate measure given in time before 10 percent of a group of bearings fail.)



Effect of belt speed on predicted bearing L_{10} life (CEMA Belt Conveyors for Bulk Materials, 7 th Edition).

Increased Erosive Wear

Generally, erosive wear is proportional to the square of the speed.

E = Mass of worn particles divided by the total mass of errosive particles.
Typical values of E are between 10^{-5} to 10^{-1}.

$$E = k\frac{\rho V^2}{2H}$$

Where:
k = Percentage of particles in a stream that impact the surface and cause wear
ρ = The density of the worn material
V = Impingement velocity
H = Hardness of the worn material

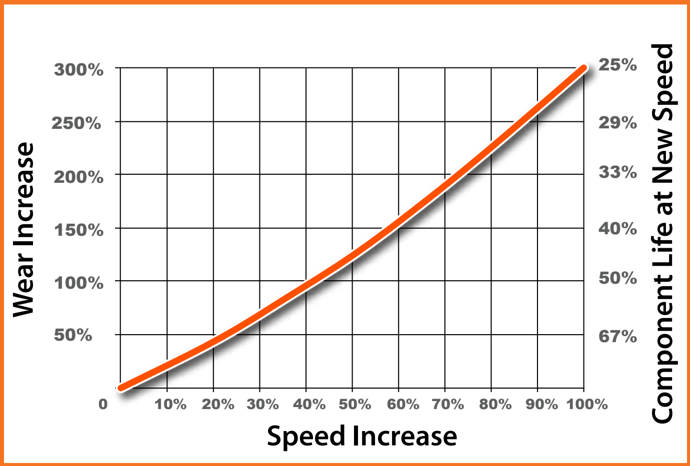
represents less than 10 percent of the total cost of the project over its useful life.

Applying a life cycle cost methodology to the selection and purchase of conveyor components would prove beneficial. As Ron Moore points out in "The business case for life cycle cost," published in 2008 in *Reliable Plant* magazine,

> Most agree that applying life cycle cost principles will improve long-term performance of the assets being developed. But, project engineers are typically measured on the project's budget and schedule, not on life cycle cost performance, thus providing a strong incentive to focus on lowest installed cost and to ignore life cycle principles, especially when using such principles results in a perceived budget overrun or schedule delay.

In this model (**Figure 31.9.**), the principle applied is that if we spend a little more money and time at the front end of the project, the returns will be

If the conveyor speed is increased by 25 percent, the erosive wear on liners and components in contact with the belt increases by more than 50 percent. The result is increased maintenance man-hours, additional wear material budgets, and more frequent outages for maintenance. These must be considered as the real cost of upgrading by raising belt speed.



Anticipated component wear increase at increased operating speeds (from www.ewp.rpi.edu/hartford/~ernesto/S2004/FWM/Notes/so9.pdf*).*

Increased Flow Problems and Choked Chutes

Changes in conveyor speed result in changes in the bulk material's discharge trajectory, which can lead to significant material-flow problems. Many times, there is not sufficient room in the plant to increase the discharge chute size for proper redirection of the stream of material. The material flow can become congested as it strikes the chute wall, which results in some of the material being suspended with a fall velocity of zero. As the conveyor feed starts and stops, layers of material accumulate on the chute wall from the zero velocity phenomenon. Over time these buildups can accumulate, only to fall and plug the chute with a lump of material when the conveyor is shut off.

Increased flow can result in higher impact loads on liners and idlers if the chute cannot be reconfigured to direct the flow with minimal impact. In addition, the increased material flow can overwhelm belt-cleaner systems and produce quantities of carryback that cannot be handled by the existing dribble chute.

The following figure shows the loading spoon of a conveyor where belt speed was increased by 33 percent to increase capacity. However, physical constraints prevented changing the chute geometry to control the flow. This resulted in direct material impact, rather than sliding, on the ceramic liners, breaking and dislodging many tiles, and quickly wearing holes in the outer chute.

Loading spoon chute liner damaged from direct material impact.

> delayed but well worth it, since they apply over the life of the equipment. Minimum life cycle cost provides maximum long-term profits! But, how do we know what the return might be. What's the payback? It's difficult to say, thus making it less attractive for project engineers to accept and apply the use of life cycle cost principles.

Moore goes on to conclude:

> My opinion is that the 10 percent extra initial cost on a project, given that it is spent to minimize design faults and thus minimize life cycle costs, is money well spent. It has a notional payback of 18 months, and will go a long way toward addressing the risk of future losses—production, costs and injuries.

Owners often transfer capital costs to future maintenance and operations costs to meet the availability of capital. Burdensome problems, such as system under-performance, excessive maintenance costs, and accidents are born by the conveyor operation and maintenance personnel every day for the life of the conveyor, often without adequate funding or staffing. The result is that ignoring problems through deferring capital costs into maintenance expense rarely results in the problems being addressed, let alone corrected.

Arbitrarily transferring costs from capital to maintenance and operations budgets results in designing to the budget rather than designing for **Production Done Safely™**.

Unfortunately, many project owners are unwilling to fund the costs for a proper upfront design and so end up with less than expected production and profit. What the owner's purchase instead is a marginal design with significant risk of suffering regulatory scrutiny, reduced conveyor availability, accidents, injuries, and a generally low level of work quality and quantity.

It would be far better to purchase, design, build, and operate an upgraded conveyor system, as this system will allow the operation to provide **Production Done Safely™**, and in that way achieve its goals for output and profitability. ⚠

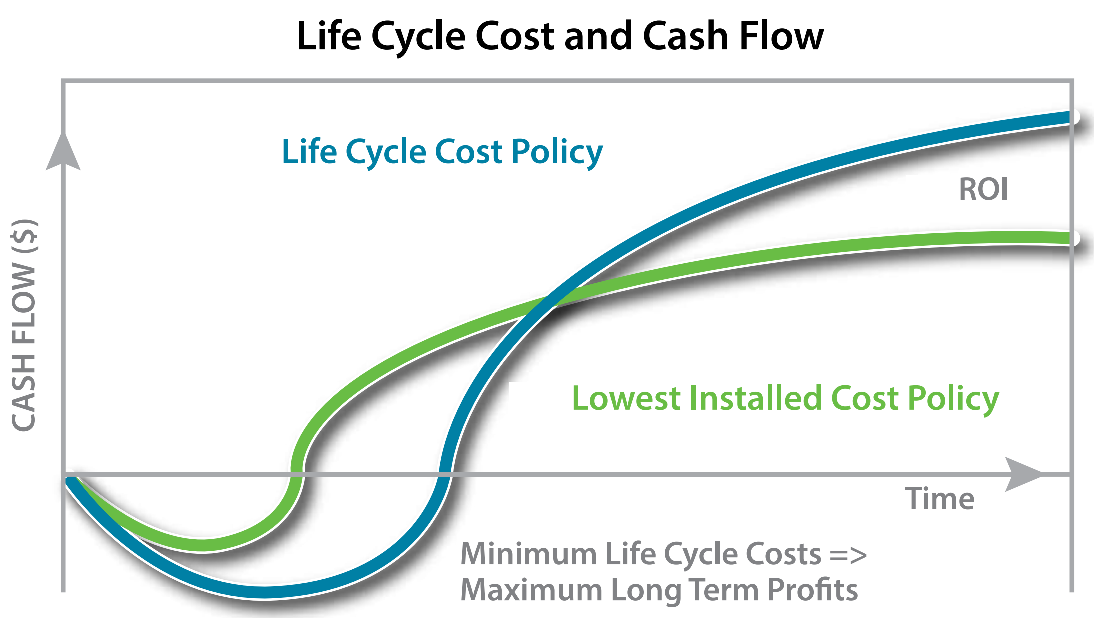
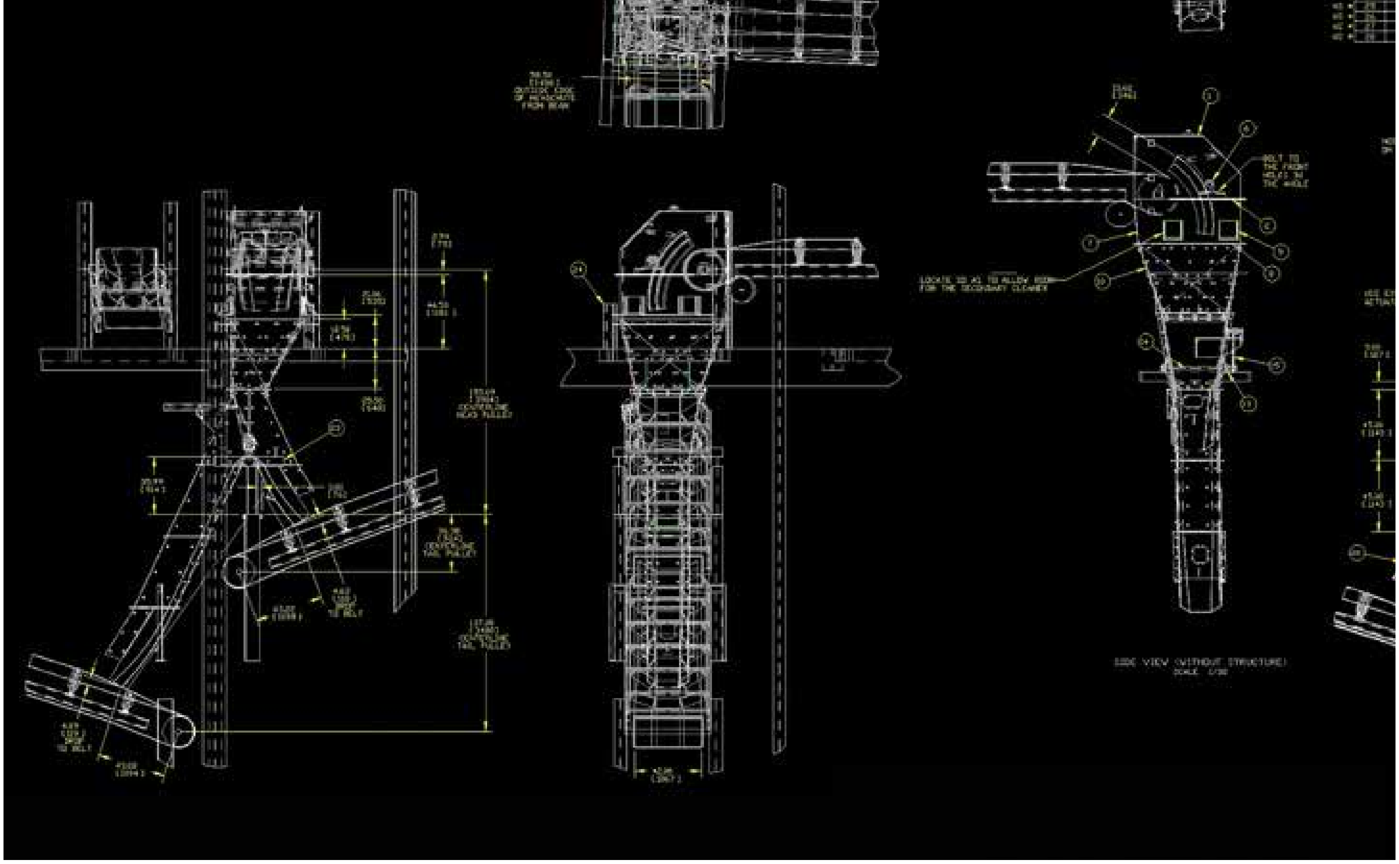


Figure 31.9.

Life Cycle Cost and Cash Flow

(Illustration after graph in Ron Moore article, "The business case for life cycle cost" on reliableplant.com.*)*

5



Chapter 32 Specifications for Cleaner, Safer, More Productive Conveyors

INTRODUCTION
The Goal of Design

Design is the process of developing a set of documents that detail the specifications, drawings, and procedures for a component system. These documents allow the system to be manufactured, installed, operated, maintained, and disposed of, in order to safely and reliably meet the requirements of the user in a cost-effective manner.

A designer's job is to produce a design that functions well and satisfies all the other requirements of the purchaser, as well as regulatory requirements. This process involves compromise and judgment. The result of the design process depends upon qualitative and quantitative analysis by the designer, and therefore, the experience and knowledge of the designer have a large influence on the outcome. A successful design requires many trade-offs between form and function. The result of this process is rarely, if ever, a perfect solution.

Design Hierarchy

There is a business aphorism: 'You can have any two of the following: low cost, fast service, high quality. But you cannot have all three.'

A selection must be made: Which two of these have the highest priority and what should be sacrificed for the best outcome? Basically, it requires the establishment of a design hierarchy.

A design hierarchy is a useful tool for ranking options in the feasibility, concept development, specification, and design processes.

When designing a system or component to be safe, clean, and productive, the conveyor designer should weigh design decisions based on the following design hierarchy:

1. **Production Done Safely™**
2. Cost Effective
3. Upgradeable

The primary function of the conveyor system is to deliver the required production capacity. But the modern interpretation of this rule is that production should be accomplished in a manner that considers safety equally important to capacity, or else it is not really productive. The monetary costs are just too great and the slow downs are just too extended for an operation to be truly productive in the face of accidents and incidents.

Traditionally, conveyors are purchased as a commodity based on price using 100 percent loading with minimal consideration given to the design techniques and details that would allow them to operate cleaner, safer and more productively. Conveyors purchased on price only are seldom safe, clean, or productive.

Price should not be the primary deciding factor in the procurement of a conveyor system. Rather, the most important consideration should be the life cycle cost of the system. This is based on direct costs—price, function, meantime to failure and maintenance—and indirect costs—health and safety, environmental, and regulatory.

Typically, upgrading the conveyor is usually seen as an increase in capacity—raising the volume of material moved. In reality, very few projects to increase capacity reach their targets because the need for additional production cannot be accomplished within the physical constraints designed into the system. Anticipated future capacity increases should be identified and considered at the feasibility and conceptual design stages.

There are areas or zones of the conveyor that are more problematic than others. Traditionally, these areas are the tail, loading, discharge, and takeup zones. For a specific conveyor or operation, these trouble spots can be identified by their maintenance costs and the frequency of incidents and injury.

It is difficult to predict where operational or maintenance problems will surface. Therefore, the design should anticipate these 'typical' issues in a manner that will allow upgrading components in these areas to solve problems when and where they arise. These as-yet-unseen problems do not need to be solved by the design. However, the design should be capable of being modified and upgraded at areasonable cost in those areas where the problems arise—that is, without excessive cost and prohibitive downtime and teardown.

Goals for the Hierarchy

Production Done Safely™

1. Functionality: The design shall perform reliably for the stated purpose and capacity.
2. Safety: The design shall exceed all local codes, regulations, and standards and use current industry best practices for safety, structural, and environmental requirements.
3. Cleanliness: The design shall minimize the generation and contain the release of fugitive materials.

4. Serviceability: The design shall be service-friendly.

Cost-Effective

1. Standardization: The design shall use standard and interchangeable components of the appropriate duty rating whenever possible.
2. Cost: Price shall not be the primary consideration in the specification of components.
3. Cost of Ownership: The design shall perform its stated function at an acceptable life cycle cost.

Upgradeable

1. Improvable: The design shall be upgradeable for improving safety, cleanliness, or productivity.
2. Access: Adequate space and access for upgrading components to increase reliability or function shall be considered in the design.
3. Planned: If an increase in capacity is anticipated during the life of the conveyor, the owner shall specify this increase. The conveyor design and physical layout shall include design and layout details that will allow the increase in capacity at an acceptable life cycle benefit.

Considerations for Specifications

Because there is an infinite number of conveyor configurations and purposes, it is not practical to offer a detailed specification that covers all possible situations. Rather the concepts and requirements that contribute to a safe, clean, and productive conveyor are listed in checklist form in the following. These points for consideration can be used by the conveyor designer as general guidelines, in conjunction with the customer's detailed specification issued with a Request for Proposal (RFP).

Any specification citing 'as recommended by CEMA' refers to information published in 2014 by the Conveyor Equipment Manufacturers Association (CEMA) in *Belt Conveyors for Bulk Materials, 7th Edition*.

Any design specification referring to transition distance and standard edge distance should consult *DIN 22101 Continuous Conveyors – Belt Conveyors For Loose Bulk Materials – Basis For Calculation And Dimensioning*.

The specifications for conveyor idlers should consult *CEMA Standard 502 – Bulk Material Belt Conveyor Troughing and Return Idlers – Selection and Dimensions* or *DIN 15207 – Continuous mechanical handling equipment – Idlers for belt conveyors handling loose bulk materials – Main dimensions.*

Conveyor Considerations

1. Feasibility Study
2. Concept Development
3. Bulk Material Characteristics
4. Tail and Transition Zones
5. Loading Zone
   A. Center Loading
   B. Skirtboard
   C. Sealing
   D. Passive Dust Control
   E. Active Dust Control
   F. Flow Aids
   G. Access
   H. Guarding
6. Carrying Zone
7. Discharge Zone
8. Sensors and Controls
9. Maintenance

1. Feasibility Study

The design and component considerations for a clean, safe, and productive conveyor system are often ignored in the feasibility study stage but can have a major positive contribution to the return on investment. The recommendations in this section should be included in

5

addition to what is considered classical feasibility study methodology.

The cost of the engineering, procurement, construction and operation of the bulk-materials-handling conveyor system is typically included in an evaluation of a proposed project to determine whether a bulk material can be mined or processed economically. There are three types of classical feasibility studies used in the evaluation of major projects incorporating bulk-materials-handling conveyors: Order of Magnitude Feasibility, Preliminary Feasibility, and Detailed Feasibility.

Order of Magnitude Feasibility

Order of Magnitude Feasibility studies (sometimes referred to as 'scoping studies') are an initial financial appraisal of an inferred mineral resource. They involve a preliminary mine plan including conveyors and major pieces of process equipment, and are the basis for determining whether to proceed with an exploration program and more detailed engineering work. Order of Magnitude studies are developed by copying plans and factoring known costs from existing projects completed elsewhere and are accurate to within 40 to 50 percent.

Preliminary Feasibility

A Preliminary Feasibility study is a more detailed than Order of Magnitude Studies. A preliminary feasibility study is used in due diligence work, determining whether to proceed with a detailed feasibility study and used as a 'reality check' to determine areas within the project that require more attention. Preliminary feasibility studies are done by factoring known unit costs and by estimating gross dimensions or quantities once conceptual or preliminary engineering and mine design has been completed. Preliminary Feasibility studies are completed by a small group of multi-disciplined technical individuals and have accuracy within 20 to 30 percent.

Detailed Feasibility

Detailed Feasibility studies are the most detailed and will determine definitively whether to proceed with the project. A detailed feasibility study will be the basis for capital appropriation, and will provide the budget figures for the project. Detailed Feasibility studies require a significant amount of formal engineering work, are accurate to within 10 to 15 percent, and the formal engineering can cost between one half to one and a half percent of the total estimated project cost.

1.1 Financial Analysis Approach

Net Present Value (NPV)

Net Present Value is the preferred method of evaluating a project that has a life of more than one year. There are two reasons for this. One, NPV considers the time value of money, translating future cash flows into today's dollars. Two, it provides a concrete number that can readily be used to compare an initial outlay of cash against the present value of the return. By looking at all investments and costs in terms of today's dollars, management can compare various assumptions and options to decide whether the project is worthwhile.

When comparing several designs and deciding which one to pursue, there are generally two options available: Return On Investment (ROI) and net present value (NPV). Net Present Value is the present value of the cash flows at the required rate of return of a project compared to the initial investment. The drawbacks to the Net Present Value method are the inaccuracies involved in estimating future operating and maintenance costs and what time value of money—called the discount rate—to use.

To construct a Net Present Value analysis comparing different conveyor design options, an analysis needs the initial cost of the conveyor, the annual costs of maintenance and operation over the life of the conveyor, and the cost of money. Many companies look at the cost of haulage in units such as cents per ton/mile [km] conveyed. The NPV analysis lends itself to this approach.

Most companies have an established cost of money—the required internal rate of return or cost of capital—used for reviewing projects, often expressed as an interest rate. The cost of money for a company is often significantly higher than the current prime bank rate because of the sources of money—borrowing and/or selling shares and/or from profits—and the risks of the investment are usually higher than the risk a bank would take when lending at prime.

1.2 Component Costs

Life Cycle Costing

Life cycle costing is using the NPV approach to compare the initial price of a component to the full cost of the component over its life.

Analysis of a project's financial return should be based on life cycle costing for the conveyor components. Rather than just comparing initial purchase prices, the cost of the component over time should include the initial price plus the cost of maintenance and operating issues over the expected life of the component. Often a more expensive component—based on purchase price—will be a lower-priced component when the full life cycle cost is considered.

To construct a life cycle cost comparison, an analyst will need the prices of components to be compared, the costs of installation, costs of maintenance, the salvage values of the options, and their expected service lives. A NPV calculation can then be made to compare components. The same limitations apply to this method—primarily the difficulty in obtaining reasonable estimates of maintenance costs and component life.

1.3 Intangible Costs

Value of a Statistical Life

Anything that matters can and should be evaluated and included in the project financial analysis. There is a general belief that many of the intangible factors which influence the return on investment for a project cannot be quantified. These factors include safety, health, and morale.

The statistical value of a life is a method of quantifying how much a company or an individual could afford to spend to improve the difficult-to-measure (intangible) safety aspects of the project.

It is well established that the most effective way to identify and correct problems is as early in the design process as possible. By including the positive returns for the intangible costs, the justification for more spending upfront on specifications and designs that improve cleanliness, safety, and productivity is obvious.

By asking how much a company is willing to spend to improve safety—or long-term health or morale—and knowing the probability of an incident occurring, management can calculate the additional amount of investment that can be made. Because these costs and returns have long been deemed unquantifiable, the numbers are often startling. Obtaining even a small percentage of the predicted savings will reap great benefits.

1.4 Capital Costs

Deferred Capital Costs

The capital cost for a project is often set in the Detailed Feasibility stage years before the final specifications and designs are completed. Invariably new problems and design issues arise during the specification and detailed design process but owners are hesitant to revisit the capital budget. What is often done is to promise to correct the issues later, usually once the system is commissioned. However, corporate managers generally have a short memory span and rarely add the necessary funds to the operating and maintenance budgets to make the deferred changes.

Deferring capital operating and maintenance costs to stay within the constraints of the original capital budget is a major reason the estimated throughput of a project is rarely achieved.

After construction, operating budgets are inevitably squeezed, and the deferred portions are rarely realized. The practice of deferring capital costs to operating costs should be discontinued because the failure to properly fund capital costs has a direct impact on safety, cleanliness, and productivity.

1.5 Maintenance and Cleaning Costs

Estimating Maintenance Costs

Often maintenance staff level is based on the mean time between failure (MTBF) and the meantime to repair (MTTR) major pieces of equipment or on bearing L_{10} hours. The assumption is that between incidents, the maintenance staff will be adequate to maintain all the minor components and secondary systems. This approach dramatically underestimates typical conveyor maintenance requirements for a clean, safe, and productive system. It leads to a mentality of 'treating the symptom' in order to get back in production, instead of the proven maintenance practice of identifying and rectifying the root causes.

Many conveyor components suffer shortened lives due to the release of fugitive materials, and/or damage from other than normal wear. Failure to adequately staff and train the maintenance department will result in a reduction in the life of conveyor components from 30 to 50 percent. Inadequate maintenance training and staffing is one of the five main root causes of accidents and unplanned outages.

1.5.1 Maintenance Personnel Requirement

- Maintenance Manager – One minimum.
- Supervisor/Foreman – One per 6,000 meters [≈20,000 ft] of conveyor.
- Mechanics – Seven per 15,000 meters [≈50,000 ft] of conveyor; or two mechanics for every four transfer points. (Minimum of two).
- Electrician – Minimum of one.
- Inspector/Planner – One for every 25 transfers or 10 percent of skilled labor (maintenance) force. Minimum of one.

1.5.2 Anticipated Conveyor Component Parts Replacement

- Carrying Idlers – every 3.5 to 7 years.
- Return Idlers – every 2.5 to 5 years.
- Belt Splice Life – based on complete revolutions of the belt (cycles)
- Mechanical Fasteners/Multi-Ply Fabric Belt – 15,000 cycles
  - Vulcanized Splices/Multi-Ply Fabric Belt – 200,000 cycles
  - Vulcanized Splices/Steel-Cord Belt – 500,000 cycles
  - Feeder Belts – every 6 to 12 months.
- Belts subject to large lumps and severe impact – every 1 to 2 years.
- Belts handling sized materials with moderate impact – every 3 to 5 years
- Specialty Belts (high-temperature, chemical-resistant etc.) – every 1 to 2 years.

1.5.3 Cleaning Staff Requirements

Cleaning around conveyors is necessary regardless of the quality of the design or the level of maintenance. Adequate maintenance staffing will reduce the requirements for cleaning by a significant ratio. If adequately staffed, budgeted, and well managed, good maintenance can reduce cleaning labor requirements by 80 percent. Arrangements where the cleaning staff does not report to the maintenance department result in an absence of accountability and foster friction between departments. Therefore, it makes sense to make the cleaning staff part of the maintenance staff.

Todd Swinderman's paper, *Measurement & Control of Spillage & Leakage at Conveyor Transfer Points*, presented at the International Materials Handling Conference (Beltcon 4) in 1987, reported an average of 0.016 hours of manual cleaning labor is required per ton of bulk material handled. This paper also indicated that the average rate for manual cleaning by shoveling as 0.5 to 1 ton per hour.

To estimate cleaning requirements in worker hours for a proposed conveyor project, multiply the tons to be handled annually by the factor specified below.

- Mines/Concentrators/ Sinter Plants 0.0250
- Smelters 0.0130
- Coal 0.0260
- Coke 0.0300
- Pulp and Paper 0.0240
- Cement. 0.0060
- Chemical/Fertilizer 0.0110

At least one laborer for manual cleaning is required for every 500 meters [≈1,650 ft] of belt conveyors.

2. Concept Development

2.1 Use industrial and urban planning concepts in plant layout.

- Consider separate traffic patterns for mobile equipment, maintenance access, and pedestrian traffic.
- Consider location of fire and rescue facilities, location of support facilities, and utilities.
- Consider the effects of future capacity expansion and associated construction activities.

2.2 Minimize the number of transfer points.

2.3 Investigate alternate layouts to minimize the number of conveyors with multi-directional discharges or moving transfer points.

2.4 Minimize the number of reversing conveyors.

When reversing conveyors are specified, choose drives with clutches on both terminal pulleys. Avoid center drives on reversing conveyors.

2.5 Design conveyors so they are inclined no more than 5° at the loading point to prevent material slip back. Use vertical curves into the incline portion with a minimum radius according to CEMA or German Institute for Normalization (DIN) calculation methods. This is especially important where heavy precipitation exists or when the shape of the bulk material tends to roll down the conveyor.

2.6 Conveyor capacity should be calculated according to CEMA recommendations for belt speed, belt width, using the DIN standard belt edge calculation. The carrying capacity should be de-rated according to CEMA recommendations to less than theoretical 100 percent standard cross-section loading. CEMA recommends de-rating to 85 percent of the standard capacity for most materials and 80 percent for difficult to handle or dusty materials.

2.7 The desire for additional capacity is a virtual certainty over the life of a plant or mine.

This should be discussed with the owner during the feasibility stage and the response documented. The impact of future capacity increases on the system and process should be included in the concept development.

Significant operating, maintenance, cleaning, and health and safety issues arise when trying to increase capacity simply by increasing belt speed. Significant cost escalation—on the order of 25 to 100 percent additional—can be incurred if the upgrade retrofit was not planned for during the original concept stage.

At a minimum, the ability to modify chute flow patterns and skirtboards as well as using wide-base idlers should always be part of the conceptual design. These changes would allow cost-effective future capacity upgrades by modifying the width and/or speed of the belt, and/or the belt's troughing angle.

2.7.1 Capacity increase potential, given constant material, belt speed, and belt width:

- Changing from 20° to 35° idlers = 27 percent capacity increase.
- Changing from 35° to 45° idlers = 8 percent capacity increase.

- Increasing one (standard) belt width, at constant trough angle = 28 percent capacity increase.
- Increasing one belt width 6-inches [≈150 mm] and going from 20° to 45° trough angle = 75 percent capacity increase.

  For example: installing 48 inch[1,200 mm] 20° wide base idlers and then changing to 54 inch [≈1,400 mm] 45° standard base idlers on existing 48 inch [≈1,200 mm] wide base structure.

  Values based on *CEMA Belt Conveyors for Bulk Materials, 7th Edition*, Tables 4.42 through 4.44, 100% CEMA capacity at 20° surcharge.

3. Bulk Material Characteristics

Proper classification and identification of the bulk material to be handled is critical to a clean, safe and productive conveyor. It is very common for the end user to change bulk material specifications after the conveyor design has been finalized resulting in a system that cannot reach its capacity or availability requirements. This often results in disputes over performance of the system. The system guarantee should clearly state the ranges of at least the bulk material characteristics identified below, and disclaim any performance guarantees when the material falls out of the specified ranges.

- Loose and conveyed bulk density ranges
- Free moisture ranges
- Angles of repose and surcharge ranges
- Lump size ranges
- Particle size distribution ranges
- Friction angle ranges for wall (liners and chutes), internal and interface (components/accessories in contact with the belt) friction factors.
- Range of adhesive stress between the bulk material and surfaces it contacts and cohesive stresses for the bulk material
- Use the CEMA 550 standard to specify additional characteristics such as abrasive or hazardous materials.

4. Tail and Transition Zones

Proper design at the tail assures the belt will be centered and conform to the trough and idler configuration as it enters the loading zone. This will minimize future problems including spillage and belt damage. To improve performance and belt life, CEMA and DIN both recommend full transition for the tail and up to one-third transition for the discharge. **(Figure 32.1.)**

4.1 Calculate the required transition distance using DIN 22101, rather than using 'lookup' tables.

4.2 Follow CEMA recommendations for full trough transition distance at the loading end of a conveyor.

4.3 Follow CEMA recommendations for no more than one-third trough at the conveyor discharge.

4.4 Consider eliminating transition idlers in the tail zone as they seldom add support to the belt and cost more than standard idlers.

Outside the load zone, return to the conventional design with idlers mounted to the stringer without shims. Inside the load zone, shim the idlers for retrofit or upgrade. (**Figure 32.2.**)

4.5 Start loading after the second full trough angle idler. Do not load mate-

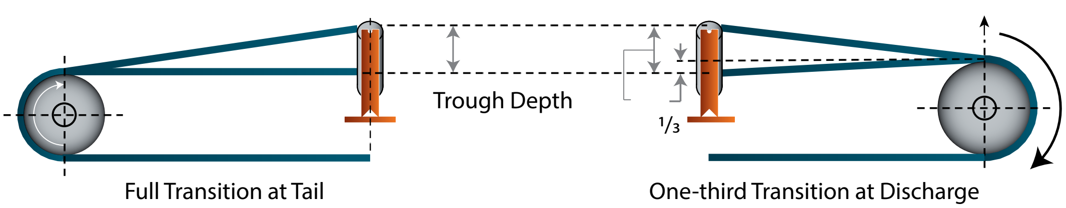


Figure 32.1.

Using the correct transition distances at the head and tail of the conveyor will assure proper belt troughing and reduce future problems.

5

rial in the tail zone while the belt is in transition.

4.6 Specify a larger tail pulley than the minimum diameter pulley compatible with the specified belting.

Select the largest diameter of the tail pulley based on:

1) The diameter required by ANSI/CEMA B105.1 based on 100% of the belt modulus.
2) At least the minimum diameter recommended by the belt manufacture for the tension at 100% of the belt modulus and recommended splice safety factor, and:
3) The space needed between the top and bottom runs of the belt for accessories such as return belt plows, tail protection plows, and impact cradles. **(Figure 32.3.)**

4.7 Consider the use of a lagged tail pulley to improve tracking in wet environments.

4.8 Avoid the use of winged tail pulleys; if required, use wrapped or chevron-style wing pulleys. Maximum belt speed for

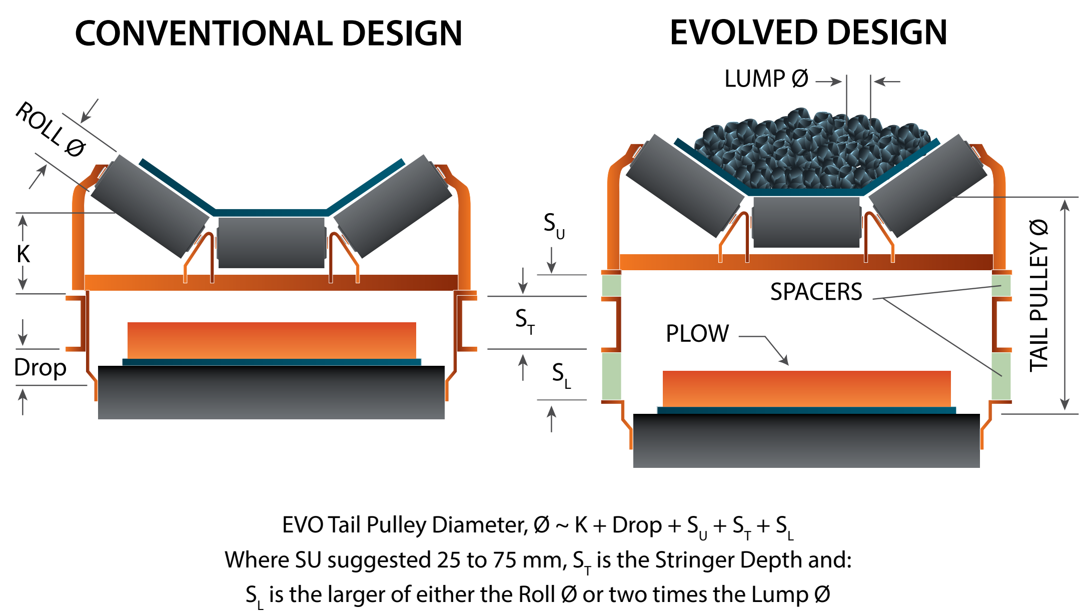


Figure 32.2.

The difference between a conveyor bought on price (left) and a conveyor using a larger tail pulley and raising the idlers to improve cleaning (right).

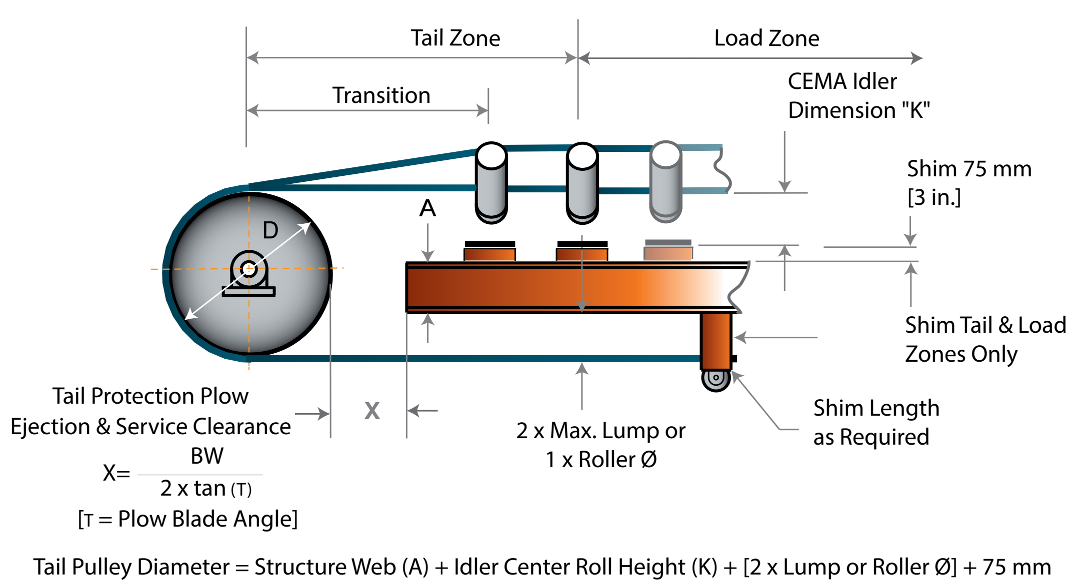


Figure 32.3.

Using a tail pulley that is larger than the minimum required by the belting will provide more space for installation and service of components such as tail protection plows and impact cradles.

5

using winged tail pulleys per CEMA is 450 feet per minute [≈2.3 m/sec].

4.9 In designing structure, consider load-zone clearances to verify fit for return belt plows and other common load-zone accessories.

4.10 Provide a tail pulley protection plow.

4.11 Arrange tail pulley support structure so that the tail protection plow can eject the largest lump or a single fallen troughing idler roller. Clearance from the bottom of stringer/structure to the ground to be 2.0 times the largest lump or the idler roll diameter.

4.12 Pave the area around the tail pulley and transition to make cleaning easier.

4.13 Provide convenient utilities—including electricity, compressed air, and sump or drain—near the tail for cleaning and maintenance.

4.14 Provide weather protection from the tail pulley to the end of the loading chute.

5. Loading Zone

Properly loading material onto a conveyor belt can significantly increase the life of the belt and other components, reduce fugitive material, and reduce maintenance needs and injury risks. **(Figure 32.4.)**

5.1 Include tail box seal to seal the high-impact and air-pressure region at the base of the chute and receiving belt interface. Extend wear liners and skirtboard seals along the tail box.

5.2 Follow CEMA guidelines for access and conduit/piping free zones. See *Belt Conveyors for Bulk Materials, 7th Edition*, Table 2.28 and Figures 2.29 through 2.35.

5.3 Load with receiving conveyor as close to horizontal as possible to reduce slip-back of material and reduction of capacity.

The capacity of the conveyor is reduced when loading on the incline through a reduction in the effective surcharge angle as the cosine of the conveyor incline. Particularly where there is a strong rainy season or the bulk-material shape tends to roll backward, loading at less than 5° helps to control slip-back of material and resulting spillage and chute plugging.

5.4 Start loading no sooner than the second fully troughed idler.

5.5 Consider using Discrete Element Method (DEM) chute design software to confirm chute dimensions will not cause pluggage and will center load in the direction of belt travel with the material velocity as close as possible to belt speed.

5.6 Idler spacing in the load zone should be designed to limit belt sag to 1 percent or less and arranged in common arrays that consider future upgrading to use seal support and impact cradles/beds.

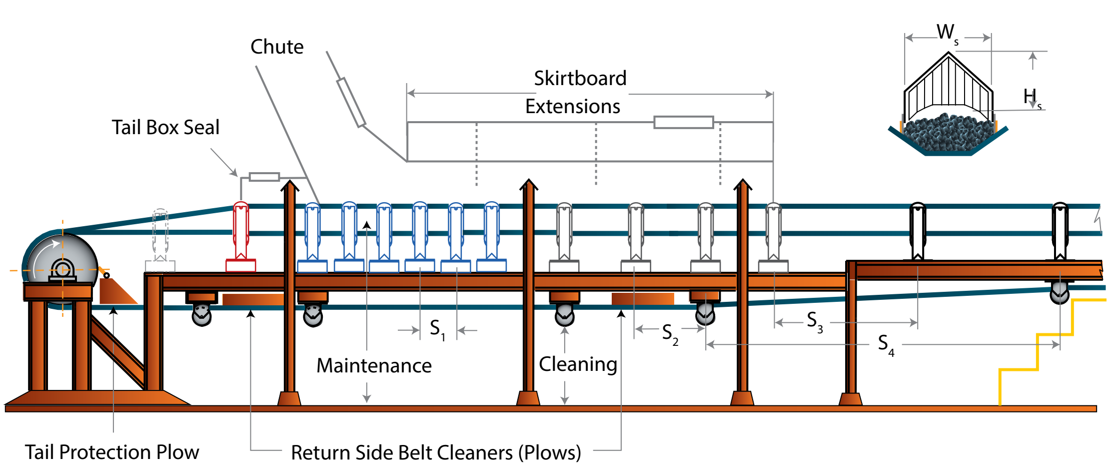


Figure 32.4.

Tail structure and loading zone designed for cleaning, maintenance, and dust control.

Guarding not shown.

5

S_1 – Idler spacing directly in the impact region should be no more than 300 millimeters [≈12 in.].

S_2 – Idler spacing under the skirtboards, but outside the direct impact area, should be based on maximum allowable belt sag of 1 percent. Spacing of 600 millimeters [≈24 in.] is common.

S3 – Idler spacing after exiting the skirted section should be governed by the overall belt sag specification but not greater than 3 percent. Spacing of 1,200 to 1,500 millimeters [≈48 to 60 in.] is common.

S4 – Return-idler spacing is based on idler loading and dynamic (belt flap) mitigation. Typical spacing is 3 meters [≈10 ft], with additonal pre-drilled mounting holes spaced to vary return roller location, if needed to address belt flap after start-up.

5.7 Idler Selection should be based on *CEMA Standard 502: Bulk Material Belt Conveyor Troughing and Return Idlers – Selection and Dimensions* or *DIN 15207 Continuous mechanical handling equipment – Idlers for belt conveyors handling loose bulk materials – Main dimensions*.

5.7.1 Idlers under the load zone generally require more frequent replacement than in other locations. Idlers in locations S1 and S2 should be designed for removal and replacement without the need to move adjacent idlers. Typical solutions include lay down end brackets and individual segmented idler rollers on a guide system.

5.8 Conveyor structure to be buildup-resistant and arranged for ability to upgrade components through use of larger tail pulley and structural arrangement and clearances.

5.8.1 Cross braces to be angle iron installed to point up.

5.8.2 Channel stringers to be installed with legs outward for easier cleaning and improved access to component mounting bolts.

5.8.3 Decking (if used) and skirtboard cover plates should be sloped to minimize material accumulation.

5.8.4 Install inclined surfaces on beams as dust plates to reduce material accumulation.

5.8.5 Protect structural base plates from corrosion and damage by mounting on raised pads.

5.9 Return Side Belt Cleaners (Plows) should typically be 45-degree 'V' design for unidirectional belts and 45-degree diagonal plow for reversing belts.

5.9.1 Install one return side belt cleaner in the area under the tail box

5.9.2 A second return side belt cleaner can be installed in the area under the discharge end of the skirtboards.

5.9.3 Install return idler(s) or slider bars to support the belt under return side belt cleaner (plows) to improve cleaning performance.

5.9.4 Consider control and collection of the material removed from the belt by plow. Provide access for easy inspection and maintenance.

Note: With reversing belts, material cleaned by reversing plows will discharge on both sides of the belt depending on belt travel direction.

5.10 It is well known that the load-zone area is the source of much of the fugitive mate-

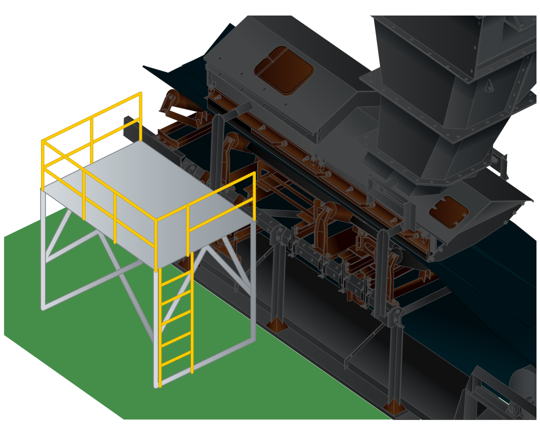


Figure 32.5.

The use of portable work platforms can eliminate the need for permanent stairs or catwalks in the conveyor loading zones.

rials. Placing steps and catwalks in this area invites slips, trips, and falls. In general, the only reasons people need to access the area are to provide cleaning and maintenance.

5.10.1 The height of the load zone above the floor should be established by the need for cleaning safely under the load zone while the belt is in operation. A secondary consideration—based on frequency of the activity—is for maintenance access.

5.10.2 Locate the return rolls 48 to 54 inches [≈1,200 to 1,400 mm] from the floor (with appropriate return-roll guards) to allow safe cleaning.

5.10.3 By using portable work platforms, there is no need to start the steps or catwalk in the load zone. Alternately space the steps and catwalk away from the conveyor and use temporary work platforms. This will improve safety and prevent unauthorized adjustment of components in the load zone. Start the steps outside of the areas where spillage is likely to occur. **(Figure 32.5.)**

Once the conveyor leaves the load-zone area, the height of the return rollers above grade can return to a normal distance. Note that most standards say a minimum of 300 mm [≈12 in.]clearance between the return roll and grade. That is probably not adequate for mechanized cleaning under the conveyor.

5.11 Use CEMA Standard 575 to specify impact beds/cradles. If cradles are not included in the original specification, design to allow for future installation in the impact area by arranging structure for the necessary space for installation and service.

5.12. Center Loading

If large lumps are handled or high-impact loading is anticipated, consider installing a tail protection plow designed to protect the belt and tail pulley by handle the impact of lumps or broken idler rolls.

5A. Center Loading

Center loading of the receiving belt is critical for proper belt tracking and to reduce the release of fugitive materials.

5A.1 Belt wear can be reduced by controlling the flow of the bulk material in the chute and directing the flow toward the receiving belt at a loading speed as close as possible to the receiving belt speed.

5A.2 Loading spoons or kicker plates are often used to help center the load. These items are subject to accelerated wear and should be designed for easy access replacement, without restrictions for confined space entry. **(Figure 32.6.)**

5A.2.1 Generally, the least amount of belt wear from loading is using a curved kicker plate that steers the material in the direction of the receiving belt travel with the horizontal component of the flow vector as close to the receiving belt speed

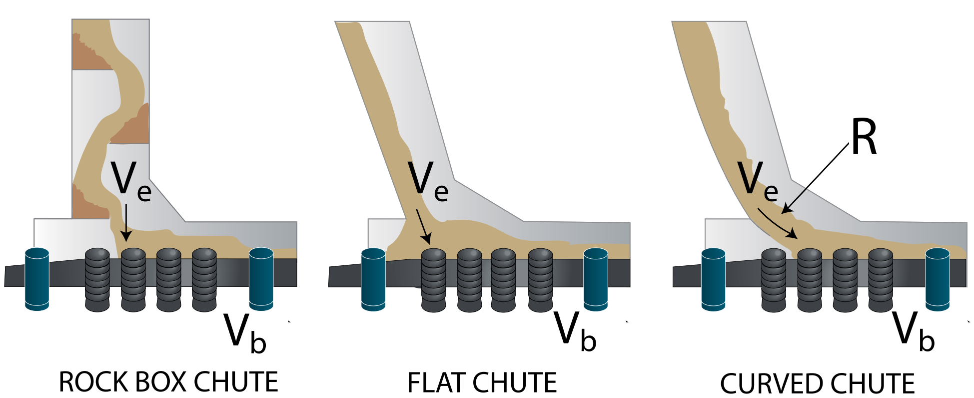


Figure 32.6.

The design of the loading chute affects material trajectory, which in turn affects belt wear rates.

5

as possible. The next most belt-friendly loading is generally a flat sloped chute. Rock boxes may cause the most belt wear because there is very little velocity in the direction of the receiving belt and the drop height can be significantly more than from a curved or flat chute.

5A.3 Consider the use of Discrete Element Modeling (DEM) software to confirm the effect of load-centering designs.

5A.4 Wear liners in the chutes should be considered sacrificial. Rather than focus on the cost and life of the liners, focus on ease and speed of replacement. Consider making the chute modular with the shell made of abrasion-resistant (AR) plate without liners. Modular panels can be reused simply by moving worn panels to a non-wearing position, or by replacement of the complete panel.

5B. Skirtboard

The skirtboards are the structural portion of the enclosure that contains the material when loading. Typically, the wear liner and sealing systems are attached to the skirtboards, and the skirtboards are covered to control dust and spillage.

5B.1 Skirtboard width should be set to a minimum of 115 millimeters [≈4.5 in.] free belt edge—measured on the belt troughed outer surface from belt edge to where the skirtboard plane intersects the belt. The skirtboard dimension is considered an imaginary plane and the thickness of the skirtboards is typically not considered when making capacity and depth of the belt of material calculations. Note: The skirtboard distance from the edge is not the same as the standard edge distance used for capacity calculations.

5B.2 Minimum recommended cross-sectional area for the loading chute at the top of skirtboards to be four times the area calculated using the material's loose bulk density and the design capacity of the conveyor.

5B.3 The connection between the exit of the chute and the top cover of the skirtboards should be sloped in the direction of belt travel to reduce chute backup.

5B.4 After the loading chute exits into the skirtboards (other than feeders), the wear liners are to be relieving (opening) in direction of travel to reduce plugging from surge loading. Note: Skirtboard structural steel can be spaced parallel to the belt. (**See 5B.5**)

5B.5 The distance of the bottom edge of the steel skirtboard above the belt is dictated by the wear liner and sealing systems. Typically the skirtboard can be parallel to the belt surface and spaced 50 millimeters [≈2 in.] or more when using an external wear liner design above the belt.

5B.6 There are several formulas which can help determine the required skirtboard length.

Based on turbulence: L_S =1.2 m per every 1.0 m/s belt speed [≈2 ft per every 100 fpm].

Based on material slippage:

$$L_s = \frac{V_b^2 - V_y^2}{2.0 \times g \times (\mu_b - \tan \theta)}$$

Based on passive dust control:
L_s = 2.0 seconds x belt speed (in meters per second or feet per second).

- L_s = length of skirtboard extension past the loading chute = L_S.
- V_b = belt speed.
- V_y = the vertical velocity of the material stream as it exits the loading chute and hits the belt.
- g = acceleration due to gravity.
- μ_b = coefficient of friction between the bulk material and the belt.
- θ = the angle of incline of the belt.

Skirtboard height should be based on limiting exit air speed to 1 m/s [≈200 ft/min] or

5

slower. Height is calculated based on total air flow and the width of the skirtboards.

Total airflow can be measured on existing loading chutes by measuring airspeed under all loading and start-up conditions and the cross-sectional area above the material flow:

$$Q_{tot} = V_{air\text{-}max} \times A_{skirtboard\ exit}$$

5B.7 Skirtboard height based on air flow (Q m^3/h or ft^3/min) calculations:

$$Q_{tot} = Q_{Displaced} + Q_{Induced} + Q_{Generated}$$

- Displaced air is the air displaced when the flow of bulk material first enters the transfer enclosure.

$$Q_{dis} = \frac{tph}{\text{Bulk Density}}$$

- Induced air is the air drawn into the transfer enclosure by the vacuum created when particles separate as the material discharges from the belt into the transfer enclosure. Screens can generate significant amounts of induced air.

$$Q_{ind} = 0.078 \times A_u \times \sqrt[3]{\frac{R \times S^2}{D}}$$

- A_u = chute open area (m^2).
- D = average particle diameter (m).
- R = capacity (mtph).
- S = drop height (m).
- Q_{ind} = induced air flow (m^3/s).

Note: This is a curve fit equation. For Imperial units, use 0.078 = 10.0.

- Generated air is the air created by process equipment or the chimney effect of long inclined galleries. Crushers are common sources of generated air. NIOSH offers this equation for hammer mills where D = diameter and W = width of the mill.

$$Q_{gen} = \frac{\pi}{4 \times D^2 \times W} \times rpm$$

Most equipment suppliers can provide generated air data for their equipment.

5B.8 Skirtboard covers should be sloped to the sides of the conveyor to resist dust buildup.

5B.9 Consider modular skirtboard designs so that the initial installation can be easily extended in length and/or height if necessitated by changes in bulk material characteristics or belt speed.

5B.10 A return belt tracking device should be installed in place of the last return roller before the load zone to steer the belt into the tail pulley and loading zone. The tracking device should be far enough from the tail pulley to allow the belt to be steered, but still close enough to the tail pulley to steer the belt into the loading.

5C. Sealing

An essential way to reduce fugitive material is to control the spillage of materials off the sides and tail of the conveyor.

5C.1 Install a tail box on rear of transfer chute.

Tail box sealing material should lay inside the tail box so that it forms a one-way seal. This will allow material on the belt to pass under, but not allow material from inside the chute/skirtboards to blow or flow backward out of the tail box. Install inspection door on top of tail box seal. The tail box should extend a minimum of one S_1 space past the back of the loading chute; it can extend to the tail pulley.

5C.2 Use an external wear-liner system, where liners are attached to the outside and bottom of skirtboard steel.

Wear liners are designed as sacrificial wear plates but they also keep the pressure of loading off of the sealing strips. The bottom of the liner should extend close to the belt; 10 millimeters [≈0.38 in.] is suggested for typical applications in the impact region. This clearance should then gradually open (self-relieve) in the direction of belt travel.

5C.3 Use a self-adjusting skirtboard sealing system to eliminate the need for continuous adjustment and the risk of over-adjustment which leads to grooving the belt.

Note: It is more important for the skirtboard sealing material to have a lower abrasion index than the belt's index, than for the sealing material to have a lower hardness rating than the belt.

5D. Passive Dust Control

Controlling the flow of material in chutes using hood and spoon technology will greatly reduce dust loading by controlling the amount of air induced into the transfer and reducing bulk-material degradation.

5D.1 Consider the use of DEM software to confirm the chute design to control bulk-material flow.

5D.2 The cross-sectional area of the skirtboard enclosure should be sufficient that the air speed exiting the enclosure is ≤ 1.0 meter per second [≈200 ft/min].

5D.3 At least three dust curtains should be installed inside the skirtboard extension.

5D.3.1 The first two dust curtains should be configured to restrict airflow. but not completely block the airflow. for example, each curtain slit into strips, with each curtain half or two-thirds the width of skirtboard enclosure. Curtains should be attached to alternate sides of the skirtboard. Curtain material should be flexible so that it moves and resists buildup.

5D.3.2 The last dust curtain to be 1.0 times the belt width inside of the skirtboard extension and the full width of the skirtboard enclosure. The curtain should be cut into strips and contoured to just clear the load on the belt.

5D.4 The skirtboard enclosure cover (roof) shall be slanted to resist dust buildup.

5D.5 Structural elements to be orientated to resist dust and material buildup; for example, angle iron members designed with the point up.

5D.6 The air flow in the transfer chute should be measured for retrofit applications or calculated for new designs.

Include displaced, induced, and generated airflows. See Martin Engineering's *FOUNDATIONS™ Book, 4th Edition*, Chapter 7 Air Control.

Calculate—or, on existing installations, measure—airflow volume and velocity.

Do not rely solely on *Industrial Ventilation* recommendations for exhaust air volume based on belt width.

5E. Active Dust Control (Suppression and/or Collection)

Dust control can be accomplished in several ways.

Dust suppression uses water or water enhanced with chemicals to reduce the creation or escape of dust. Systems apply moisture as a spray, foam, or fog.

Dust collectors use fans to pull dust-laden air into a filtration media. System alternatives include large central collection systems and smaller, localized air-cleaning systems.

Consult Martin Engineering's *FOUNDATIONS™ Book, 4th Edition*, Chapter 19 Dust Suppression and Chapter 20 Dust Collection for general guidance on active dust control systems. Consult a supplier for recommendations for specific applications.

5E.1 Consider suppression to manage the escape of dust; dust suppression can be accomplished in many ways. Due to the addition of water and/or chemicals, dust suppression may affect product quality. Because of water-use restrictions, the cost of chemicals, and nozzle maintenance issues, many processes unnecessarily shy away from dust suppression.

5E.2 If the measured or calculated airflow is greater than 56 cubic meters per minute [≈2,000 ft^3/min], consider providing active dust collection.

5E.3 Do not use *Industrial Ventilation* recommendations for cfm of exhaust volume based on belt width as they may dramatically over- or underestimate the volume of air.

5E.4 If central dust collection is used, follow *Industrial Ventilation* recommendation for location and sharing of exhaust volumes, but not the extraction volumes.

5E.5 If modular dust collection is used, place collector unit one-third of the skirtboard extension length from the exit of the skirtboards and between two dust curtains.

5E.6 Consider providing mounting location(s) for dust suppression and/or collection equipment in the original design to make future retrofit upgrades cost-effective.

5F. Flow Aids

Flow aids typically used on transfer chutes to enhance flow and prevent material buildups in chutes are air cannons and vibrators.

Consult Martin Engineering's *FOUNDATIONS™ Book, 4th Edition*, Chapter 9 Flow Aids for general guidance. Consult a supplier for specific recommendations.

5F.1 Consider including the location and mountings for flow aids in the original fabrication to make future retrofit installation of flow aids more cost effective.

5F.2 Consider isolating the discharge chute between the head chute and skirtboards to make it a 'live' chute that can be vibrated to reduce buildups and blockages.

5F.3 Use safety cables to tether flow aids to the structure in case they come loose from their mounts.

5F.4 For safety, air cannons and vibrators should only activate on positive air pressure.

5G. Access to the Load Zone

Frequent inspection and maintenance are required to contain fugitive materials. It is certain that there will be the need for occasional cleaning of spillage and fugitive materials in the loading zone. Both inspection and cleaning often contribute to serious accidents.

5G.1 Arrange the height of the loading zone for maintenance. Cleaning access areas should be designed to improve access and promote ergonomically friendly service procedures.

5G.2 The distance from the working surface (floor or walkway) to the bottom of the return rollers should be sufficient to allow safe cleaning under the moving belt providing that return-roller nip points and any other identified hazards are properly guarded. A typical height to allow cleaning is a minimum of 1.2 meters [≈4 ft].

5G.3 Troughing idlers, wear liners, skirt seals, and dust containment/suppression equipment should only be accessible by authorized inspection and maintenance personnel. To control access, consider eliminating walkways around the load zone and providing temporary work platforms rather than fixed platforms.

5G.4 Allow at least one belt width distance after the exit of the skirtboard before installing steps to walkways. If fixed walkways/platforms are provided along the load zone, properly guard the load zone and/or install a limited access means such as a lockable gate to keep unauthorized personnel out of the load zone.

5G.5 If fixed walkways/work platforms are provided along the load zone, calculate the required structure loading based on the platform being completely covered with bulk material at its angle of repose.

5G.6 Follow CEMA guidelines for access and conduit/piping free zones. (See *CEMA's*

Belt Conveyors for Bulk Materials, 7th Edition, Table 2.28 and Figures 2.29 through 2.35.)

5G.7 Pave the area under and around the loading zone to make maintenance and cleaning easier and safer.

5G.8 Provide utilities and tools needed for cleaning and maintenance in the immediate area. Utilities could include power, welding outlet, compressed air, water, and sump or drain. There should also be brooms, shovels, and specialty adjustment tools in a suitable storage compartment.

5H. Guarding

Many serious accidents occur while workers are around the conveyor's loading zone to perform maintenance and cleaning.

5H.1 All loading-zone nip points on the belt's carrying side should be guarded.

Many standards treat loading-zone nip points between the loaded belt and the idlers as a non-hazard if the skirtboards/wear liners are 50 millimeters [≈2 in.] above the belt.

This practice should be discontinued as even with 50 millimeters [≈2 in.] of space, the weight of the loaded belt and the pressure of the skirt seal make the interface between the loading chute, skirtboards, and belt into a dangerous nip-point hazard.

5H.2 If there is access via fixed work walkways and/or platforms, use area guarding.

Area guarding should be interlocked to the conveyor drive. The trend is to provide both interlocked area guarding for general protection and proximity guarding.

5H.3 If the load zone is designed for cleaning while the belt is in operation, all return rollers and the belt line edges should be guarded to prevent accidental contact.

5H.4 Protection from materials falling from the belt should be provided based on the nominal size of the bulk material.

Generally speaking, material lumps smaller than 50 millimeters [≈2 in.] should not normally present a hazard but an accumulation of fugitive materials on an elevated structures might.

6. Carrying Zone

In the carrying zone there are fewer, but still important, details, to consider in order to provide a clean, safe, and productive belt conveyor.

6.1 Access is critical in all areas but especially for inclined conveyors. Access should be provided on both sides of an inclined conveyor for service and inspection.

Most codes require a minimum walkway width of 600 millimeters [≈24 in.] for occasional service access and 900 millimeters [≈36 in.] for general access. There are other ways to provide service access such as mobile maintenance platforms that travel above or below the structure.

6.2 Replacement of return idlers is a common activity which exposes the worker to the risk of injury. As with carrying side idlers, changing return idlers creates ergonomic and safety issues.

Inspection and maintenance of idlers is the main function requiring access on both sides of the conveyor. Even a 1,200 millimeters [≈48 in.] idler can easily weigh 40 kilograms [≈88 lb] and pose ergonomic (muscle strain) and safety (dropping, pinching) issues when trying to service from one side.

6.3 Walkway access on both sides is often placed on structural extensions from the bottom of conveyor trusses. This practice places the return idlers below the walkway and thus makes inspection and replacement more difficult and dangerous than necessary. Consider lowering the walkway below the return idlers, or provide a mobile work platform or ground surfaces and clearances suitable for bucket lift operation.

6.4 Access means free access; do not allow bend pulleys or auxiliary equipment to extend into the walkway. Provide wider walkways in these areas and install a handrail barrier to prevent tripping over such equipment.

6.5 Provide access to both sides of inclined conveyors for inspection and maintenance. See *CEMA's Belt Conveyors for Bulk Materials, 7th Edition*, Chapter 2 Table 2.28 and Figures 2.29 through 2.35.

6.6 Most standards do not require guard-ing nip points between the belt and the carrying idlers even though these hazard points are numerous and exposed in most designs. Consider installing handrails or barrier guardrails between the belt and the walkway(s).

6.7 On all conveyors, consider a means for crossing over and under conveyors where necessary. Many components on the carrying side need frequent access for inspection and service; crossovers should be provided to alleviate the temptation to climb on the belt to cross over. Some codes require crossovers for overland conveyors at intervals established in the regulations. See *CEMA's Belt Conveyors for Bulk Materials, 7th Edition*, Chapter 2, page 47.

6.8 The structure of the carrying zone should lend itself to modularization for guarding.

6.9 Consider covers on the carrying run of the conveyor to reduce: windblown dust, moisture additions to the bulk solid, wind blowing the empty belt off the idlers, or to serve a secondary function of guarding nip points.

6.10 Tracking idlers on the carrying zone are generally not needed if the belt is center loaded, the structure is in alignment, and the idlers are aligned to the belt centerline.

6.11 Provide adequate lighting along the carry zone for access and maintenance.

6.12 Nip points between the belt and convex curves in conveyor must be guarded due to higher tensions in the curved area.

7. Discharge Zone

The discharge zone is a frequent location of accidents and should be designed for ease of access to allow inspection and maintenance.

7.1 Follow *CEMA's Belt Conveyors for Bulk Materials, 7th Edition*, Chapter 2 guidelines for access.

7.2 The structure should be designed for access to the safety sensors such as belt wander and chute pluggage switches.

7.3 Adequate surge capacity for normal stopping conditions should be included in the discharge chute design or an overflow means provided.

7.4 The structure should be designed to allow for mounting of belt cleaners according to CEMA's access recommendations for primary and secondary cleaning locations. See *CEMA's Belt Conveyors for Bulk Materials, 7th Edition*, Chapter 2.

7.5 On inclined conveyors, consider horizontal mounting of the backstop arm to open up access for installing and maintaining belt cleaners.

7.6 The location of the service platform should be conducive to ergonomic inspection and service of belt cleaners. Belt cleaners should be at least 39 inches [≈1 m] from the service platform.

7.7 Provide utilities required for cleaning and maintenance at the discharge area.

7.8 If flow aids are used in the discharge chute, interlock them to the access doors to prevent accidental activation with the access doors open.

7.9 Provide reasonable sealing/covering for access doors, shafts, and belt entry and exit to reduce the area to allow induced air.

7.10 The trajectory of the material should contact the chute/wear surface at an angle that does not create a zero-falling velocity for any portion of the bulk material to reduce chute buildup, potential blockage, and reduce the hazard of this material falling down the chute during operation or maintenance.

7.11 Consider making the chute modular with the shell made of abrasion-resistant (AR) plate without liners. Modular panels can be reused simply by moving worn panels to a non-wearing position or by replacement of the complete panel. (**Figure 32.7.**)

7.12 The cord for the pull-cord emergency-stop switch should go completely around the discharge chute and tail pulley.

7.13 Provide adequate lighting in the discharge zone.

7.14 Use a larger head pulley than the minimum required by the belt specification to aid in installing multiple primary cleaners on the head pulley. 48 inches [≈1,200 mm] recommended. (**Figure 32.8.**)

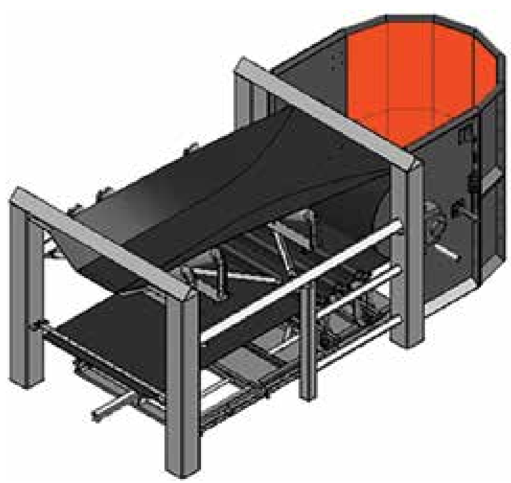


Figure 32.7.

Polygon discharge chute with modular panels.

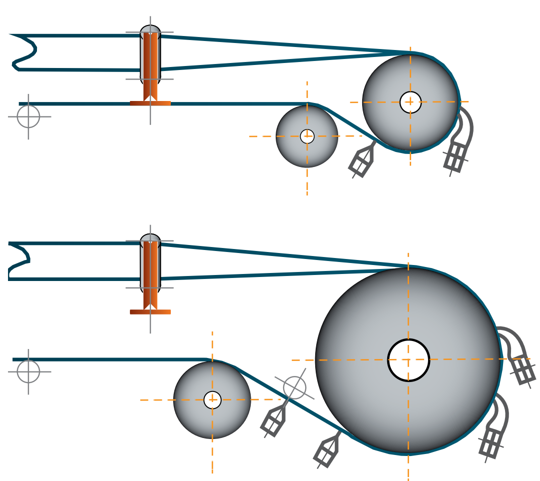


Figure 32.8.

Larger head pulley allows for adequate cleaning.

7.15 Extend the discharge chute to enclose the snub pulley.

7.16 When belt cleaners are installed off the head pulley, install a pressure roller above each cleaner.

7.17 Dribble chutes should be vertical whenever possible or when angled, use a live back-wall design. (**See Martin Engineering's *FOUNDATIONS™ Book, Fourth Edition*, Figure 9.16.**)

7.18 Consider the use of in-line planetary gearboxes on head pulley-driven conveyors to allow access to the drive side mountings of the belt cleaners or use service-friendly cleaners that can be adjusted and serviced from the operator side without the need to access the drive side.

7.19 Consider the location of the snub pulley in relation to the head pulley to allow installation of belt cleaners in the secondary position. Most belt cleaners will require a minimum of 6 inches [≈150 mm] clear access for each cleaner. The access platform should be located at least 39 inches [≈1 m] below the cleaners for ergonomically friendly service of cleaners. (**Figure 32.9.**)

Consult the belt cleaner manufacturer for dimensions for belt cleaner installation and structural clearances necessary for installing the cleaner tensioner.

7.20 Use the CEMA Classification system for the severity of the belt cleaning application and the CEMA Carryback Levels for specifying the required level of belt cleaning.

7.21 To aid in dust control, the head pulley enclosure should extend to include the snub pulley or at least the last troughing idler before the belt reaches the head pulley.

8. E-Stops and Safety Sensors/Controls

It is important to conveyor safety and productivity to accurately monitor the conveyor, and in the event of problems, to stop it from any place along the system.

8.1 Belt Misalignment Switches

In the load zone, the tracking of the belt into the load zone is fundamental to center loading and to avoid many other operational and maintenance issues.

Install two-stage belt misalignment (wander) switches on the return run between the last return idler and the tail pulley. The first stage should be a warning; it is set to allow normal belt wander. A typical warning value is +/- 50 millimeters [≈2 in.] The second stage should be an e-stop setting based on the amount of travel possible before the belt contacts the conveyor structure or moves out from under the skirt seal.

8.2 Pull-Cord Emergency-Stop Switches

A pull-cord emergency-stop switch should be accessible on both sides of the conveyor—if both sides of the conveyor are accessible—and around the tail and head pulleys.

8.3 Zero-Speed Switch/Tail Pulley Rotation Sensor

Install a speed or rotation-sensing switch on the tail pulley shaft. Avoid using exposed sensor targets as they present a safety hazard.

8.4 Belt Speed/Motion Detector

Consider adding a belt speed/motion detector to work in combination with the tail pulley speed/rotation sensor.

8.5 Belt-Rip Detector

Consider installing a belt-rip detection system with an e-stop function if it is believed that tramp metal or sharp slabs of material can penetrate the belt upon loading impact.

8.5.1 Consider including space for the future addition of a rip-detection monitor immediately after the impact region of the load zone even if such problems are not anticipated under current operating conditions.

8.6 Fire/Smoke/CO Detectors

Fire/smoke/CO detectors are often required by code based on the nature of the bulk

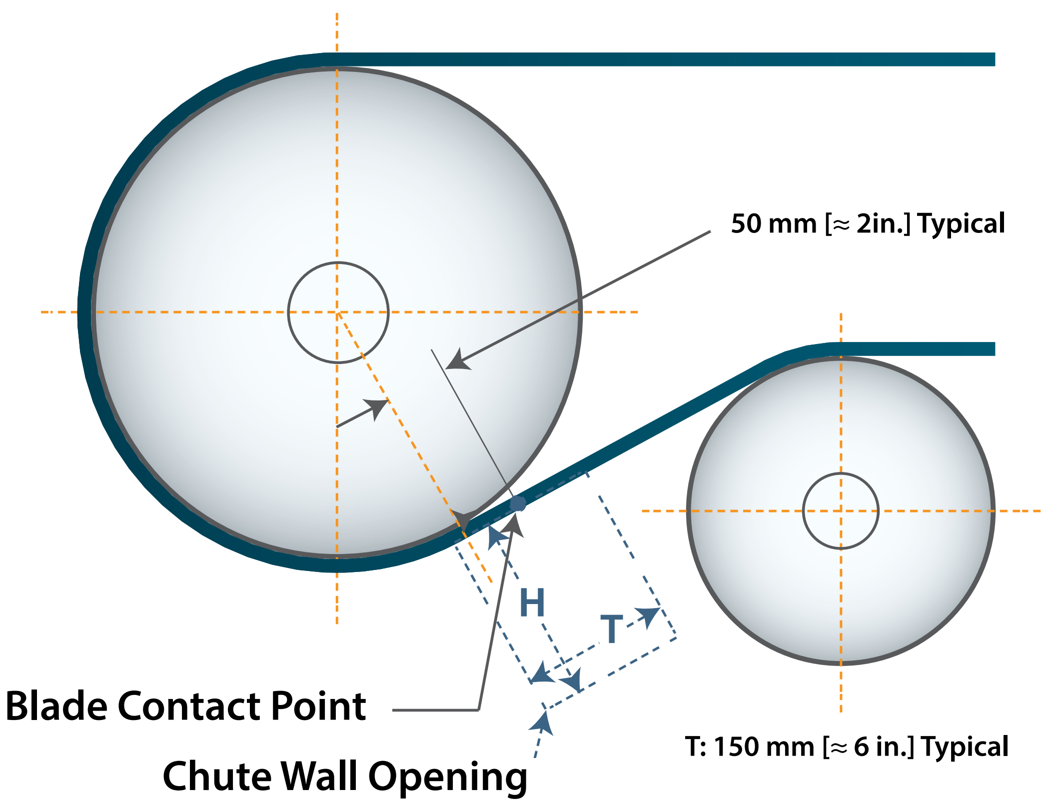


Figure 32.9.

Geometry related to position of snub pulley and space required for belt cleaning.

5

material conveyed. The most common form of fire control is a water deluge system with fused nozzles.

8.7 Material Flow Sensor

Consider adding a bulk-material flow sensor at the exit of the skirtboards as a warning for plugged chutes.

9. Maintenance

Loading-zone components need regular inspection, adjustment, and periodic replacement. They should be designed to allow easy service that does not require entry into confined spaces

9.1 Service-friendly components should include:

- Tail box end seal
- Tail protection plows
- Wear liners
- Skirtboard seals
- Dust curtains
- Idlers
- Belt cleaners
- Belt support structures: idlers/impact beds/slider cradles under the load zone
- Active dust collection/suppression equipment

CLOSING THOUGHTS
The Value of Typical Specifications

These typical specifications are intended to assist system designers and owners determine what is important to achieve clean, safe, and more productive conveyors. Spending additional time on design greatly reduces the risk of project failure, reduces operating costs, and improves safety. While it is impossible to specify every option, every consideration, or every variable in a general publication, these are intended to offer guidance as to what should be considered in developing a conveyor system. ⚠

5

Section 6

THE PAYBACK

Chapter 33 Accounting for Safety

INTRODUCTION

There is an old adage: 'If you think safety is expensive, try an accident.'

Accidents, incidents, and industrial illnesses are costly, as the authors will show, with both direct and indirect expenses and consequences. Safety—that is, those things that can be donte to prevent or avoid accidents, incidents, and illnesses are then lumped together in the cost for safety. Expenses for safety are always—in some ways—a means of cost avoidance.

But rather than just seeing expenses, many workplaces are now recognizing a positive return from their investments in safety. These positive benefits are visible in enhanced productivity as well as safer conditions. This provides a prompt and meaningful return on investment.

This chapter will consider the economic factors of accidents and of investments in safety.

6

> *"In my experience, a strong safety performance translates into a strong business performance."*
>
> *Cynthia Carroll,*
> *CEO (1/2007 to 10/2012)*
> *Anglo American plc*

> *"Just because it's hard to capture and measure the specific financial benefits of reducing injuries doesn't mean we should shy away from discussing safety's impact on an organization's bottom line."*
>
> *Danny Smith,*
> *"The Other Side of the Coin"*
> *Occupational Health & Safety*
> *April 2015*

The Costs of Accidents

Fully understanding all the costs associated with a workplace injury can be difficult. A number of organizations—including both the National Safety Council (NSC) and the Centers for Disease Control and Prevention (CDC) in the United States—have models that attempt to estimate the costs. But the different models can vary greatly.

In an article, "The Other Side of the Coin," published in *Occupational Health & Safety* in April 2015, Danny Smith reported, "The average medical cost of lost-time claims alone is $36,592," according to the National Council on Compensation Insurance in the United States. He noted, "Because that number has risen every year since 1995, the cost of the medical treatment of workplace injuries is likely to continue increasing."

As specified in "The ROI of Safety" by Kyle W. Morrison from the June 2014 issue of *Safety+Health* magazine, the "CDC's estimate shows a fatal injury carries an average cost of about $991,027. This average includes only hospital costs." In 2012, the NSC assessed the average economic cost of a workplace fatality as $1.42 million, with a disabling injury averaging $53,000.

These figures, although high, are likely to be lower than the actual cost of a single death

Cost for a Disaster: $11 Million a Death

The 1991 paper, *Reducing Mine Accidents by Design*, written by J.H. Daniel of the United States Bureau of Mines and published by the Society for Mining, Metallurgy, and Exploration, reported that the average fatality cost to an underground coal mine was $1.02 million (USD). This figure includes medical, worker compensation, accident investigation, loss of income to family, and lost coal production costs, but not equipment loses. Costs for an accident in an underground coal mine were estimated at $237,000 per injury in cases involving permanent disability and $5,000 per injury in cases involving worker lost time.

When considering fatalities, these costs can be measured against the scale of the 2010 Upper Big Branch Mine Disaster in the United States. This mine explosion and fire—the worst coal mining disaster in the United States in nearly 40 years—resulted in the deaths of 29 coal miners. The disaster resulted in massive losses to the mine owner, Massey Energy, and the firm's new owner, Alpha Natural Resources. According to an article on *theguardian.com* titled, "Who will pay for the Upper Big Branch mine disaster?" by Beth Wellington, these costs included:

Massey Costs	$128.9 Million	Including rescue costs, fines, family payments and, a write-off of an estimated loss of $56 million EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization) contribution.
Alpha Costs	$209 Million	
which includes	$46.5 Million	In restitution ($1.5 million for each of the two survivors and for the family of each of the fatalities.)
	$80 Million	For safety improvements.
	$48 Million	For safety research over a two-year period.
	$10.8 Million	For penalties for the accident.
	$24.2 Million	To resolve pending civil penalties at other (formerly Massey) operations.

The total of nearly $338 million brings the cost of the disaster to more than $11 million per death. These costs do not include the penalties for several former Massey officials facing trial or already serving prison terms.

In addition, Alpha Natural Resources accepted a $265 million settlement of a class action lawsuit it inherited which alleged Massey misled shareholders about the company's safety record.

Given the benefit of hindsight—or in a counter-factual alternate history universe—if the Massey operations had spent the $80 million on safety improvements—the amount now required of Alpha—and so had avoided the disaster, it would have presented a Return on Investment (**Return on Conveyor Safety™**) of more than 300 percent (3 to 1) against the (no longer required) expenses of $248 million in other disaster costs now assessed against Alpha.

because both models reflect only direct costs and do not include the indirect costs. Applying the ratio of $2.12 (USD) in indirect costs for every dollar in direct costs means that a single workplace fatality goes from costing an average of $1.42 million to costing nearly $3 million.

Direct Versus Indirect Expenses

In calculating just how much an accident will cost a business, there are two types of expenses that need to be considered: direct costs and indirect costs.

Disagreement exists about which expenses should be considered direct and which indirect, but it is commonly noted that the indirect expenses far exceed the direct expenses. The indirect expenses typically account for 70 to 90 percent of the total true accident cost; this is often portrayed as a hidden (under the water) portion of an iceberg, which is larger than the visible top. (**Figure 33.1.**)

The general definition of a direct cost is an amount of money that can be completely attributed to the production of specific goods or services. Direct costs refer to materials, labor, and expenses related to the production of a product. Other costs, such as depreciation or administrative expenses, are more difficult to assign to a specific product, and therefore, are considered indirect costs.

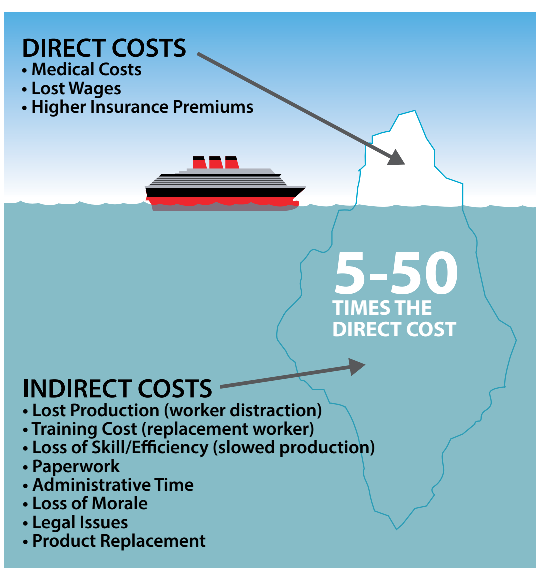


Figure 33.1.

Like the hidden portion of an iceberg, the indirect costs of an accident are typically much larger than its direct costs.

Direct costs (as related to safety) reflect those that are explicitly associated with the accident, incident, or illness. In general, these are medical bills, insurance premiums, indemnity payments, and temporary disability payments.

Indirect costs include a great number and variety of other expenses that can be attributed to the accident, incident, or illness which would not be incurred if not for that accident, incident, or illness. These costs include the value of production time lost by the injured employee, and by fellow workers and supervisors due to the accident by providing first aid and by conducting an investigation.

Other indirect costs include:

- Cleanup time and the value of spoiled product.
- Repair or replacement of equipment, and to purchase and install improved (safer) equipment.
- Overtime for existing employees to fill in for the missing worker, and for the hiring, training, and equipping of new employees, whether temporary or permanent, as well as additional administrative time to schedule personnel and production.
- Legal fees and costs for safety agency citations, penalties, and litigation.
- Increased insurance premiums.
- Production delays and missed shipments. These delays can turn into damaged relations with existing or potential customers due to the failure to meet deadlines and ship dates. This turns into unhappy customers and loss of goodwill.
- Expenses associated with lower employee morale and increased absenteeism, reduced workmanship, and loss of respect for management.
- The hard-to-calculate costs of bad publicity, increased scrutiny by regulators, the added difficulties of hiring to work in an unsafe environment, and the higher wages needed to attract workers due to risks.

All of these expenses represent funds that cannot be devoted to other more-productive ventures that will make money for the company. They represent missed profit opportunity.

Unlike the direct costs, the indirect costs are not covered by any type of insurance policies and are a direct hit to the bottom line.

Comparing the Costs

While it is often easy to forget about indirect costs because they are harder to measure, indirect costs can be more expensive than the direct costs.

Studies have shown that such indirect costs usually total three to four times the direct costs of the accident and could amount to as much as 20 times the direct costs.

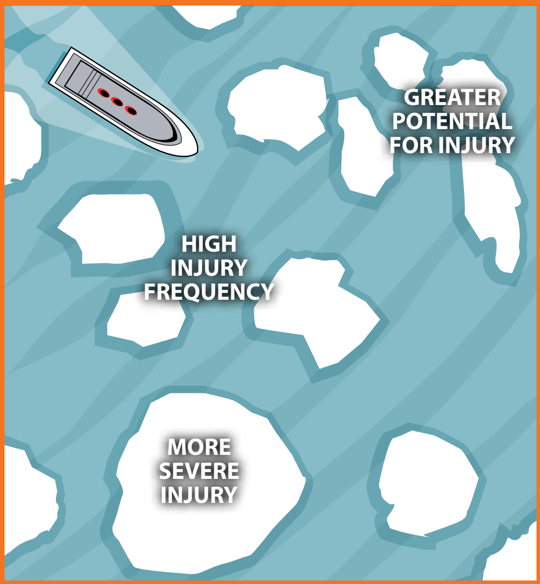
As Kyle W. Morrison specified, according to the National Safety Council in the United States, "For every dollar in direct costs, indirect costs could be as much as $2.12." A study by the American Society of Safety Engineers (ASSE) titled *Return on Investment (ROI) for Safety, Health, and Environmental (SH&E) Management Programs*, estimated the ratio of indirect to direct costs to be much higher, as much as 8 to 1.

Even the United States Occupational Safety and Health Administration (OSHA) estimates indirect costs run between 1 and 4.5 times direct costs. In addition, OSHA calculates the magnitude of indirect costs is inversely related to the seriousness of the injury. The less serious the injury the higher the ratio of indirect costs to direct costs; this is applied in the *OSHA $AFETY* online cost estimation tool. (**See The Price of Recovery: What it costs in sales to recover from an accident.**)

In addition to the differences between direct and indirect costs, another distinction between the costs of a workplace injury is that some costs can be insured against but others cannot. Typically, the uninsured costs far outweigh the insured costs. It is clear from studies that the ratio between insured and uninsured costs forms a sort of 'iceberg,' with the greater costs hidden below the surface. It is these uninsured costs that come straight off the company's bottom-line profits.

The Iceberg Analogy

Consider that owning and operating a bulk-materials belt conveyor is like navigating an iceberg-laden body of water in a boat. The direct costs of an injury are the visible portion of an iceberg floating in the water. Associated with any injury are indirect costs that are invisible. Just like an iceberg, the invisible, hidden parts are usually larger than the visible parts. The water becomes much harder to cross if there are more icebergs (greater potential for injury), larger icebergs (the injuries themselves are more severe), or the icebergs are closer together (high injury frequency). An operation can hinder itself by attempting to cross the body of water in an unresponsive, hard-to-steer boat (poor safety program). Furthermore, an operation can further hinder itself by charging into the body of water and just hoping it does not hit anything (arrogance).



The body of water is dangerous but navigable; success depends on the design of the boat, and the skills, training, and resources of the crew.

6

The Hidden Costs of Safety Failures

Anyone who has had the misfortune of witnessing or handling the aftermath of a serious or fatal on-the-job injury knows the costs go far beyond those that appear in the company's ledger. Here are just a few of the hidden costs of an ineffective safety program.

- For those who survive or who work with the accident victim, the costs continue with psychological stress that may require years of expensive therapy.
- Many times, co-workers who witness a serious event find themselves unable to return to the worksite for a significant period of time, which presents additional costs to the company through the abrupt loss of skilled workers.
- A plant with a bad reputation for safety and health may find itself unable to attract workers at all or may have to pay wages well above market value to do so.

Moreover, as more information concerning a company's safety compliance and injury experience becomes publicly available over the internet or social media, foes of industrial development may use this information to contest permit applications or zoning change requests. Part of being a good corporate citizen—rather than a company that no one wants 'in their backyard'—is offering a safe work environment to the local residents. (**Figure 33.2.**)

Getting Approval for Safety Expenses

For safety professionals whose bosses, managers, or employers do not see the value or benefit, the idea of investing in safety can be difficult to explain or justify.

The first course for safety professionals is to argue from the 'people' side of things; the company should invest in safety so workers do not get hurt, so that no families go without their loved ones.

But in addition, a telling case can be made that the safety improvement offers other business improvements—improvements that might not be perceived before the investment is made. The financial return on investment—increased productivity, improved customer service, and money savings from fewer injuries—could help with selling the improvement to management too.

The Payback on Investments in Safety

It is sometimes difficult to justify with hard numbers the payback on investments in safety. However, as the article, *The ROI of Safety*, by Kyle W. Morrison notes:

> Experts say the savings exist, and—armed with the right figures on the cost of injuries—safety pros should be able to successfully argue that investments in safety will result in savings down the line.

In a 2002 white paper, *Return on Investment (ROI) for Safety, Health, and Environmental (SH&E) Management Programs*, the American Society of Safety Engineers (ASSE) concluded, "There is a direct, positive correlation between investment in SH&E and its subsequent ROI."

The ASSE white paper also reported that 95 percent of polled American business executives believed that workplace safety has a positive impact on a company's financial performance. Of these executives, 61 percent believed that their companies received a return on investment of $3 (USD) or more for each $1 (USD) they invested in workplace safety.

The ASSE white paper noted that the United States government safety agency agreed, quoting OSHA's Office of Regulatory Analysis as saying:

> Our evidence suggests that companies that implement effective safety and health can expect reductions of 20% or greater in their injury and illness rates and a return of $4 to $6 for every $1 invested.

The 2009 article, "Financial Decision Makers' Views of Safety," written by by Yueng-Hsiang Huang, Tom B. Leamon, Theodore K. Courtney, Sarah DeArmond, Peter Y. Chen and Michael F. Blair, published in the ASSE's magazine *Professional Safety*, noted a study that explored corporate financial decision-makers' perceptions of safety issues. Survey results showed participants perceived that, on average, for every dollar spent improving workplace safety, about $4.41 would be returned.

In the article, "The Other Side of the Coin," in *Occupational Health and Safety*, Danny Smith noted:

> A 2012 paper published by OSHA cites a survey of 231 companies with more than 100 employees. It found 43 percent of financial decision-makers believed the biggest benefit of their company's workplace safety program was an increase in productivity.

The Payback on Safety Expenses

According to the conference presentation, *Safety & The Bottom Line: Proving The Financial Benefits Of Your Safety Initiatives,* by W.P. Van Den Raad, additional ROI can also be demonstrated by the positive impact safety improvements exert on productivity. Foster Wheeler Energy UK Ltd conducted "a study of their construction performance records and safety improvements for a 17 year period, encompassing some 19 construction projects." Four financial indicators were used:

1. *Cost Ratio* – (Total project control budget cost)/(Actual project cost)
2. *Schedule Ratio* – (Planned construction span in months)/(Actual construction span in months)
3. *Safety* – (Actual or estimated exposure man-hours in millions)/(Number of lost time injuries)
4. *Productivity Ratio* – (Budget field man-hours)/(Actual field man-hours).

The research found:

> … a 65% degree of overlap between improving safety and improving productivity, indicating that the cost benefits of safety are significantly higher than previously calculated using the model of reduced unplanned costs. This research showed that halving the LTA [lost-time accident] rate produced a 6% increase in productivity.

Productivity is seen as the amount of product produced per labor hour, for example, 6 percent more tons of material produced with the same amount of labor.

Van Den Raad's 1999 presentation continued:

> Even if the cost benefit is as low as a 1% improvement in productivity, it would mean a significant annual saving. For example, a company expending 1 million man-hours a year (approximately 500 employees) at an average direct labour cost of £30 [≈$45 USD] per hour would make an annual labour cost saving of £300,000 [≈$450,000 USD].

The Link to Productivity

Productivity is a term that will resonate with the chief executive officer of any operation. So

Figure 33.2.

Part of being a good corporate citizen is providing a safe working environment for employees.

6

any time the case can be made that a particular safety expenditure will increase productivity, it presents a huge advantage in selling the program, in getting the project funded. That is because the safety expense is providing a dual benefit: safety and productivity. (**Figure 33.3.**)

Rockwell Automation, in postulating its *Safety Maturity Index*, cited Aberdeen Group research, that showed:

> Best in class manufacturers realize that the combination of employee behavior, company processes and procedures, and technology implementation enable them to achieve 5 to 7% OEE [overall equipment effectiveness], 2-4 % less unscheduled downtime and less than half the injury rate of average performers.

The index also states:

> These higher-performing companies also experienced far fewer workplace accidents compared to average performers - [with rates of] 1 in 2,000 employee versus 1 to 111 employees.

It is apparent that safety and productivity are complementary. When an operation has an appropriate culture, procedures, and equipment for safety, safety performance goes up, machinery speed and utilization go up, and operational efficiency goes up. These positive results are related and interdependent.

As Danny Smith's article, *The Other Side of the Coin*, concluded,

> So even if management's goal is to squeeze the greatest amount of efficiency from the money spent on their company's safety program, one can make a strong case that rather than cut back on spending, investing more in safety—even for companies that already meet regulatory standards—will result in lower insurance premiums and higher production.

Figure 33.3.

Conveyor projects that improve both safety and productivity stand a greater chance of being 'sold' to management.

The ROI Angle

The word justification is used to describe the process by which expenditures for a project are compared to the improvements the project will make. This allows a corporation to verify that the project is done for good reason(s) with a legitimate benefit.

The way that the costs for projects are justified in many industrial operations is through a demonstration of the payback of the expense; that is, how quickly the money expended will be returned to the organization in the forms of increased productivity and profitability—and sometimes reduced problems and expenses which are more difficult to prove.

As with any other corporate project, one of the best ways to justify a safety expense is to show those who approve the expenses that the project will generate a positive return on investment (ROI).

This payback justification is usually calculated against a time frame; this establishes how long it will take for the money expended to be recaptured by the improvements brought about by the expense. If a proposed project has a payback period of less than one year, it is usually approved by plant management if the cost is within the limits of the plant-level expense approval limits.

But the payback is hard to calculate and prove for safety projects, because the expense is an investment in things that did not or will not happen; it is an investment in prevention rather than in making things happen. The payback is harder to measure and is more appropriately referred to as 'Return on Prevention.'

Return on Prevention

Accounting for the effects of the investment in occupational safety and health improvements has proven to be quite complex. As a rule, direct measurement is not possible. Traditional financial and performance management accounting systems—such as bookkeeping, financial statements, and cost accounting—do not provide suitable information.

While the improvements in safety programs give rise to expenses in the short term, the benefits of prevention emerge in the form of revenue savings in the long term.

In contrast to the more traditional accounting, prevention accounting explicitly focuses on the costs and benefits of prevention work. Prevention accounting can thus best be regarded as a specific form of cost-benefit analysis.

This return consists of the sum of the direct benefits from the prevention of work-related accidents and ill health, and the indirect benefits from secondary effects which generate economic advantages for the company.

This 'Return on Prevention' represents the ratio between the monetary benefits of prevention and the costs of prevention. The resultant key performance indicator Return on Prevention (ROP) is an abstract representation of the potential economic success of occupational safety and health. Return on Prevention expresses the direction and strength of occupational safety and health programs in helping to achieve company

The Price of Recovery: What it Costs in Sales to Recover from an Accident

Certainly the impact of an accident on a company's bottom line can be devastating. And the additional earnings required to compensate or recover the expenses lost are considerable.

OSHA has created an online tool, '*$afety Pays*,' that uses the specific economic information supplied by a company to assess the potential economic impact of occupational injuries on that firm's profitability. The program uses estimates for direct and indirect costs and weighs them against financial information supplied by the company.

For direct costs, the '*$afety Pays*' Cost Estimator uses average claim cost estimates provided by the National Council on Compensation Insurance (NCCI) in the United States.

To develop the indirect costs for an accident, the program uses a sliding scale multiplier ranging from 4.5 times (for the lowest direct costs) to 1.1 times (for the highest direct costs). These indirect cost estimates are taken from the Business Roundtable publication, *Improving Construction Safety Performance*, which in turn was based on a study conducted by the Stanford University Department of Civil Engineering.

The direct and indirect costs are then combined into a total accident cost. To calculate an accident's impact on profitability, the company's profit margin is used to determine the sales required to pay for the total cost.

The results of the calculations done through the OSHA '*$afety Pays*' program can be eye-opening, if not staggering. To consider one example, assume that Company A has annual sales of $10,000,000 with a 3 percent pre-tax profit margin. As assessed by the '*$afety Pays*' tool, the cost of a single crushing injury—a very possible injury found in facilities using high-powered belt conveyors—was estimated to be:

Average Direct Cost:	$56,557
Average Indirect Cost:	$62,212
Estimated Total Cost:	$118,769
The additional sales necessary:	
To Cover Indirect Costs:	$777,658
To Cover Total Costs:	$1,484,612

In short, to recover the costs lost due to the accident—and provide the same amount of profits—the operation in question needs to produce and sell nearly $1.5 million (USD) in additional volume. This represents an unplanned additional increase of 15 percent in sales and in production.

For more on the OSHA '*$afety Pays*' Cost Estimator, visit *www.osha.gov/dcsp/smallbusiness/safetypays/index.html.*

goals. This metric provides a concise indicator of whether, and to what extent, prevention expenses pay off for a company.

Return on Prevention was discussed in a 2011 report, *The return on prevention: Calculating the costs and benefits of investments in occupational safety and health in companies – Summary of results*, published by the International Social Security Association (ISSA). As there is a lack of hard (measurable) indicators for the benefits of occupational safety and health (OSH) prevention, the ISSA project was based on researching the perceptions and estimates of experts. The report explained:

> The results should not be over-interpreted on methodological and statistical grounds, as they are only assessments and estimates. Nevertheless, the findings are of value because those interviewed were experts within their company and the empirical studies were based on interviews representing an ambitious survey methodology.

The ISSA study also found:

> There are benefits resulting from investment in occupational safety and health in microeconomic terms, with the results offering a Return on Prevention ratio of 2.2. In practice, this means that for every 1 EUR (or any other currency) per employee per year invested by companies in workplace prevention, companies

Safety: A Boost to Corporate Performance, or Evidence of Sound Management, or Both

Companies that build a culture of health by focusing on the well-being and safety of their workforce yield greater value for their investors. That is the conclusion of a paper, "The Link Between Workforce Health and Safety and the Health of the Bottom Line: Tracking Market Performance of Companies that Nurture 'a Culture of Health,'" published in the *Journal of Occupational and Environmental Medicine* in 2013.

The researchers looked at companies that had received the Corporate Health Achievement Award (CHAA) from the American College of Occupational and Environmental Medicine (ACOEM), an annual award that recognizes the healthiest and safest companies in North America. To receive the CHAA award, companies must be engaged in demonstrable and robust efforts to reduce health and safety risks among their employees.

The study showed the CHAA award-winning companies outperformed the S&P 500 in all four investment scenarios tested.

According to the paper, focusing on the health and safety of a workforce impacts healthcare costs, productivity, and performance. These companies did not just happen to have healthy and safe workers; they built "cultures of health and safety," which in turn provided a "competitive advantage in the marketplace."

While admitting more study is needed, the authors noted, "Our results strongly support the view that focusing on the health and safety of a workforce is good business."

Perhaps the research identified an association between companies that focus on health and safety and companies that manage other aspects of their business equally well. "Although correlation is not the same as causation, results consistently and significantly suggest that companies focusing on the health and safety of their workforce are yielding greater value for their investors," the authors wrote.

In its conclusion, the report summarized its findings:

> A portfolio of companies recognized as award winning for their approach to the health and safety of their workforce outperformed the market. This may have identified an association without a causal relationship, or it may reflect the idea that companies that focus on the health and safety of their workforce manage other aspects of their business equally well.

A safe company is well-run, or a well-run company is safe. Either way, this research indicates the two categories are related; common sense tells us both are goals worth pursuing.

> can expect a potential economic return of 2.20 EUR (or any other currency).

The ISSA report concluded, “Occupational safety and health is a statutory obligation for employers that is beneficial to employees, but it is equally a factor for business success.”

The Business Case for Safety

A 2009 article, “Financial Decision Makers’ Views on Safety,” presented in ASSE’s *Professional Safety* magazine noted, “Financial executives who were surveyed said that the top benefits of an effective workplace safety program were predominately financial in nature (e.g., increased productivity, reduced costs).”

The financial benefits of programs to improve safety can be seen in three areas. First, from a loss control perspective, there is a considerable ROI from reducing accidents in that it keeps the hard-earned earnings as profits rather than as losses. Secondly, an improvement in safety performance increases productivity and increased productivity, means an increase in profits.

In addition, there is a third factor that provides a payback on a safety investment: the human benefit. The ROI in human terms can be understood to be improved morale and improved engagement from the workforce. That in itself will have a significant return on investment. That is in addition to the positive feelings in both management and the workforce generated by the satisfaction of knowing that all are doing what they can to help ensure safety.

It may seem impossible, or at least very difficult, to quantify morale. But as Douglas Hubbard suggests in his book, *How to Measure Anything: Finding the Values of Intangibles in Business*, as few as five observations can provide a good idea of an average value with an accuracy of over 90 percent. To measure morale, one might, on five different days, randomly observe 10 workers to assess how many appear happy and motivated (or at least smiling) out of the field of 10. Given five such 10-worker observations, the average score gives you a good idea of morale, assuming the association of morale with a positive happy worker. Then, at appropriate intervals after introducing a new program or some other change, repeat the simple measurements and judge if morale has improved.

A good overview of the economic benefits of safety was written by Joseph J. Lazzara in a column, “Why Machine Safety Makes Dollars and Sense,” published on *EHSToday.com*. He concludes:

> It is apparent that preventing even a single accident more than pays for the machine safety equipment many times over. When you add worker satisfaction and positive workplace attitude into the mix it becomes obvious that an investment in workplace safety makes good dollars and sense!

CLOSING THOUGHTS
The End of the Analogy

When the ship is moving through the body of water, it makes good sense to minimize the risk of colliding with the icebergs through careful navigation and wise precautions. An investment in life jackets will help crew members survive if one falls into the water or if the boat hits an iceberg. But an investment in radar to learn where the icebergs are makes more sense. ⚠

ADVISORY

USING THESE ACCOUNTING METHODS TO JUSTIFY SAFETY INVESTMENTS, COMBINED WITH A SAFETY CULTURE, CAN RESULT IN A SAFER, CLEANER, AND MORE PRODUCTIVE OPERATION.

Chapter 34 The Payback for Safety

INTRODUCTION

Safety Does Not Cost, It Pays

Hidden in an operation's accounting system are large costs that with the right approach can be uncovered and reduced by continuous improvements in safety. The savings from a robust safety culture are enormous, especially when compared to the 'old school' approach of savings from cutting operating and maintenance budgets, and may at first seem unbelievable.

For example:

- According to the article, *Return on Investment (ROI) For Safety, Health, and Environmental (SH&E) Management Programs*, published on the American Society of Safety Engineers' (ASSE) website, in 1986 at Georgia Power's two power plant construction sites, "the direct cost savings from accidents prevented was $4.14 million at one site and $0.5 million at the other."
- France-based Schneider Electric reduced its Occupational Safety and Health Administration (OSHA) recordable

injury rate from 3.6 per 100 full-time workers to 0.5 over 10 years by identifying and eliminating hazards. This resulted in $15 million annual savings in direct costs alone, as noted by Kyle W. Morrison in a *Health+Safety* magazine article, "The ROI of Safety."

In the bulk-materials-handling industry, the majority of the operations are managed for production at the expense of safety. Justifying investments in safety, whether it be training, personal protective equipment, or safer equipment, has been problematic for quite some time. The approach by governments has been negative reinforcement through regulation piled on regulation, followed by inspection after inspection, followed by fines upon fines. This negative approach has gotten the industry to a point of diminishing returns on safety as many companies now see their way to invest in safety only in order to comply with, rather than exceed, safety regulations. Statistics show that despite the enormous regulatory pressure, there has only been a marginal improvement in safety over the last several decades.

Many chapters in this book provide reasons and examples of why the current approach to safety needs to change. Perhaps the most common reasons safety investments are not made more often are two-fold. First, the conveyor will operate without safety equipment or fugitive control accessories. Second, often there is not a clear short-term return from safety expenditures.

It is difficult to resist the urge to produce—at the sacrifice of workers and equipment—when the plant and its management are judged on short-term financial results. It is more difficult for managers to convince the corporate accountants that spending money on safety will extend the lives of equipment and workers and improve the bottom line.

Perhaps the accountants are being given the wrong numbers to crunch. This chapter focuses on ways to justify investments in conveyors to provide **Production Done Safely™**.

Accounting as a Measuring Stick

Accountants use Generally Accepted Accounting Principles (GAAP) or International Financial Reporting Standards (IFRS) in the preparation of financial statements. Those statements usually consist of a profit and loss statement (P&L) and a balance sheet. A profit and loss statement is the reconciliation between income and expenses and represents activities over a given period of time; a balance sheet represents the value of the assets, liabilities, and shareholder's equity at a point in time. These statements often become public documents used by investors, researchers, and governments for a wide variety of purposes. While reputable companies want to accurately report their financial position, the companies—and their officers—also want to maximize the profit while minimizing taxes.

On the other hand, governments and safety researchers want to showcase the benefits of the investments, and so often use non-traditional (non-GAAP or non-IFRS) but recognized methods to analyze the impact of company policies on industry or the population in general. A common result of such analysis is the familiar claim by governments that the cost of a regulation is X but the benefit to society is a larger multiple of X, and therefore, the regulation presents an acceptable trade between the cost to industry and the benefit to society. This chapter will present a combination of traditional and non-traditional measurements to justify safety investments for bulk-materials-handling conveyors.

Year-end or quarterly statements in accordance with GAAP or IFRS standards are produced in an attempt to fairly represent the financial condition of the company and allow comparisons with other companies and between previous reporting periods. In the preparation of these statements, numerous estimates, averages, and reasonable assumptions are made. There are very few intangible costs or values listed in formal accounting statements. One common exception on the balance sheet is the intangible asset, 'Goodwill.' (**Figure 34.1.**)

Goodwill is a special type of intangible asset that represents that portion of the entire business value that cannot be attributed to other income-producing business assets, either tangible or intangible. The value of a company's brand name, solid customer base, good customer relations, good employee relations, and any patents or proprietary technology represent this Goodwill. Goodwill is often based on relationships or reputation that has been developed by a company as a result of a good safety record, great community relations, or other positive attributes. The value of a reputation is not converted into a monetary value for addition to the company's balance sheet, but it is very important in running a clean, safe, and productive operation.

One of the largest threats a company faces is a disaster—such as an accident with multiple fatalities or a large-scale environmental catastrophe—that ultimately results in the closure of the business. When an event of this scale happens, all of the savings produced by buying on price and then managing to the minimum personal and environmental safety standards to maximize production are lost. Such is the case with the 2010 Upper Big Branch Mine disaster in the United States that resulted in multiple deaths and exposed questionable management practices, presumably designed to maximize production while avoiding fines from safety inspections. After the accident, the company's stock value plunged from a high of about $70 per share to less than a dollar, the company's assets were sold, and it ceased to exist. Jobs were lost; shareholders and suppliers lost money and the human costs were enormous as a result of this enterprise-wide disaster. (**See Chapter 33 Cost of a Fatality.**)

Figure 34.1.

Goodwill is an intangible asset that represents the company's brand name, customer base, patents or proprietary technology, and good customer-, employee- and community-relations.

In many cases, making a decision to invest in safety based on the predicted changes in intangible costs will be seen as requiring a leap of faith that the investment will actually pay off. Corporate executives often have long-term performance goals tied to the financial results reported quarterly or annually on the formal financial statements. As a result, the executives are unwilling to make decisions that cannot be proven to produce a result on paper. In turn, operations and maintenance managers are often measured on monthly departmental budgets and production goals. Local managers who are judged on short-term results are not likely to make investment decisions that cannot be guaranteed to reduce costs or increase production within their budget cycle. And so, the cycle continues: purchase on price, manage for production, and cut direct operating costs and maintenance expenses, and yet expect improved results.

It is our contention that intangible costs are actually 'less tangible' costs that can be measured and used to justify and track investments in safety. (**See Tangible and Less Tangible Costs.**) The tracking of these investments shows an amazing effect on company finances, employee safety, plant productivity, and the well-being of the environment.

A Review of the Literature

Almost every article on safety has a statement along the lines of: 'It is obvious that safety pays.'

There are many safety articles with anecdotal savings but the industry has yet to connect the dots into a body of common knowledge and a methodology that can be used to justify investments in safety. As an industry, we have yet to give managers the tools to prove the obvious.

Almost every research article on the cost of safety addresses three categories of costs; we will call them: Employer, Human, and Community. In every case the conclusion is that the employer bears the minority of the cost while society and the worker (or the worker's family) share the majority of the costs. The costs to be laid upon the employer are estimated to range from a few percent to one-third of the total cost, with the worker and community sharing the remainder almost equally.

The foundation of **Return on Conveyor Safety™** investment calculations is to establish the costs to be reduced and the probability of a safety incident. The literature cites a number of direct costs and indirect costs for the common reporting categories of personal injuries. Reporting varies from country to country as well as definitions of classes of injuries and whether or not indirect costs are included. In distilling the data from numerous sources, the intent was to detail employer costs in **Figure 34.2** and probabilities in **Figure 34.3**.

Measuring Less Tangible Costs

Operations and maintenance managers often fail to justify those obvious investments because they do not have the data or proof for the corporate executives to feel safe in making the decision. When launching the 'next great program of the month,' corporate executives often fail to convince the local managers of the obvious benefits of the program.

In his book, *How to Measure Anything*, Douglas W. Hubbard outlines several methods to measure the value of less tangible costs and benefits to business. Two of his basic premises are: 1) that things that are directly related to making a decision should be measured, and 2) a lot of data is not required to be confident that the measurements reflect a statistically valid value. Hubbard promotes the 'Rule of Five.' This is the statistical truth that there is a 93.75 percent chance that the median value of what is being measured—that is, the point where half the values are above and half are below—will be between the smallest and largest values in any random sample of five taken from the overall group.

Incident or Activity Cost or Benefit (USD)	Minimum Value	Average or 'Default' Value	Maximum Value
Direct Cost of Fatal Accident	$56,000	$1,000,000	$2,150,000
Direct Cost of a Lost-Time Accident	$8,000	$20,000	$680,000
Direct Cost of a First Aid Injury	$900	$1,450	$2,200
Medical Costs of an Industrial Disease	$7,000	$20,000	$1,700,000
Enterprise-Wide Catastrophe	$5,600,000	$300,000,000	$600,000,000
Ratio of Direct to Indirect Costs	1.1:1	3.75:1	8:1
ROI for Safety Culture and Programs	25%	225%	600%
Increase in Productivity from Safety	2%	14%	35%
Cost of Unscheduled Downtime Per Hour	$5,000	$25,000	$50,000

Figure 34.2.

Summary of Literature: Employer Costs and Savings for Safety (USD).

Probability of an Injury or Disease per Worker per Year	Minimum Value	Average or 'Default' Value	Maximum Value
Fatal Accident	0.000038	0.00034	0.00095
Lost-Time Injury (3 days or longer)	0.00043	0.0375	Insufficient Data
First Aid Injury	0.01445	0.050	Insufficient Data
Fatal Industrial Disease	0.00043	0.00063	0.000893

Figure 34.3.

Summary of Literature: Probability of an Injury or Disease.

Using this methodology provides greater than 90 percent confidence that the estimated outcome will be achieved.

Looking at the 'Rule of Five'

The Rule of Five is a technique useful for reducing the amount of data needed to prove a need for or the result of an investment with 90 percent (or greater) confidence. It starts with picking five random samples from the population.

As Hubbard notes, the chance of randomly picking a value which is above an (unknown) median is 50 percent. There is the same 50 percent chance of selecting a value below the median.

Tangible and Less Tangible Costs

The list of tangible and less tangible costs can be extensive depending upon the complexity of the system and the size of the operation. The following list of suggestions is meant to provide ideas on where to look for costs that may have an effect on safety investments.

More Tangible Costs (easier to measure)	Less Tangible Costs (harder to measure)
Initial Capital Expenditure	Any Lost Production as a Result of Unplanned Downtime
Transportation Costs	Safety Compliance Costs
Assembly and Installation	Functionality of the System
Maintenance	Expected Component Life
Spare Parts Cost	Warranty Costs
Operating Costs	Replacement Cost
Initial Component Cost	Repair Time Prediction
Maintenance Labor Cost	Injury Case Management
Electricity Cost per Kilowatt-Hour	Medical Costs for Surgery, Medicine, and Rehabilitation
Worker's Compensation Premiums	Lost/Decreased Productivity
Loss of Products or Services	Time to Go to Medical Appointments
Government Inspections and Reports	Production Downtime
Run-In Time	Administrative Costs
Waiting on Tools or Parts	Additional Overtime Pay Required
Waiting on Operations to Clean or Shut Down the System	Time to Hire Replacement
Health Insurance Costs	Interviewing and Training New Employee
	Delays in Shipments and Filling Orders
	Negative Media Attention
	Penalties and Fines
	Attorney Fees
	Damages to Equipment, Machinery, Materials, and Facility
	Reputation Loss
	Degraded Client Loyalty and Support
	Managerial Costs Due to the Accident Including Inspections, Investigations
	Loss of Employee Time Associated with Assisting With the Accident, Administering First Aid and Witness Interviews
	Loss of Employee Morale
	Slowed Work Pace Due to Other Employees' Fear of Injury

To demonstrate: if a coin is flipped five times, the chance of getting 'Heads' all five time is 3.125 percent (50% × 50% × 50% × 50% × 50% = 3.125% chance of all 'Heads.') The same is true for getting 'Tails' every time. Therefore, the chance of at least one out of a sample being above the population's median and at least one being below the population's median is 93.75 percent (100% - (2 × 3.125%) = 93.75 %). (**Figure 34.4.**)

Thus if a random selection is made five times, there is a 93.75 percent chance that the median of the full population will be between the largest and smallest values in the group of random selections.

Here is an example: The maintenance workers have been complaining about a frequently used tool pinching them when operated. The vendor is contacted who says the tool can be repaired but it will be expensive, to the point where it becomes a 'repair or replace' decision. Furthermore, the vendor considers the tool to be safe to use and not really a hazard. Since the injuries are minor, and not recordable, the boss suggests delaying the repair until next year's budget. But some of the workers are using different, less productive methods to avoid using the tool, and sooner or later, the alternate method is going to result in a first aid incident. What would convince the boss to spend the money now?

One approach is to use the Rule of Five to obtain the facts needed to convince the boss. To do this, informally observe and record five situations. Was the tool used or not? How long did the alternate procedure take rather than the procedure using the tool?

Suppose the results show 3 out of 5 times the tool was not used and the extra time required to complete the procedure was 1 hour of labor at $75 per hour. Report to the boss, saying with 90 percent confidence that it is takes 60 percent longer (3/5) to complete the procedure, and the cost to the company is 60% x 1 hour = $45 every time the procedure is required.

Postponing the purchase of the replacement tool is shown to reduce maintenance productivity. In addition, it is not a question of 'if' there will be a first aid incident, it is just a question of 'when.' As a result, the boss agrees to have the tool replaced.

Following the purchase of the new tool, again observe five procedures and record that the tool was used every time (eliminating the unsafe 'work around') and that nobody was pinched (eliminating the risks of the old tool).

To complete the project, present the outcome data to the boss.

Calculating Return on Conveyor Safety™ (R.O.C.S.™) Investments

As a result of decades of 'Management by Objectives' and 'Buying Based on Price,' there are many more possibilities for savings from indirect or less tangible cost savings than from controlling budgets and issuing management edicts. From operation to operation, there certainly remain opportunities to reduce direct costs. But the savings from equipment, training, and programs that make an operation cleaner, safer, and more productive will offer much greater cost savings.

The management consultants EY Global looked at the issue of productivity. In a 2014 publication, *Productivity in Mining*, they noted that during the last boom cycle in commodities, the attempt by mining companies to maximize output by extending production periods or increasing throughput actually resulted in a 44 percent decrease in productivity. It took 44 percent more labor per unit of production with the management approach of cut expenses and 'run until broken' than it did before the boom.

Figure 34.4.

The 'Rule of Five' indicates there is a 93.75% chance of at least one from a five-part sample being above the median and one being below the median.

6

A number of other studies have indicated a strong link between safety and productivity.

The following sections outline various calculations useful in evaluating the Return On Conveyor Safety™ (R.O.C.S) for investments.

Return on Investment

In its most simple form, Return on Investment (ROI) is the savings produced by an improvement divided by the cost of that improvement. The time period for the establishing the direct savings and direct cost values is usually one year. (**Figure 34.5.**) ROI can be expressed in several ways: as a ratio, a percentage, or in time. While an easy concept to understand, this approach does not usually include indirect costs or take into consideration the time value of money. The ROI approach to justifying investments is best suited for basic comparison of costs not classified as capital investments; it works best for consideration of purchases with service life of less than one year and/or less than the company's established cost level for classifying purchases as capital expenditures. In other words, the investment can be expensed within a single fiscal year budget.

For longer-term investment analysis, it is necessary to consider the initial investments plus revenues and expenses that accumulate or occur over time. Except for very small companies that are allowed to account on a cash-in/cash-out basis, tax laws require companies to account for the expenses to match up with the revenues generated within a fiscal year. This type of accounting is called accrual accounting.

Costs

Costs are usually divided between direct costs, which are those costs specifically involved with production of the product or service such as labor, materials, and energy, and easily identified indirect costs, those costs for support functions such as maintenance, cleaning, salesmen, management, and even accountants.

$$\text{ROI} = \frac{\text{Total Savings}}{\text{Total Costs}}$$

$$\text{ROI} \times 100 = \text{ROI\%} \qquad \frac{1}{\text{ROI}} = \text{Years to Payback}$$

Figure 34.5.

Calculation for Return on Investment (ROI).

Costs can further be classified as fixed or variable. A fixed cost is one that does not vary with production, such as security. A variable cost varies with production, such as the amount of energy consumed.

Direct and indirect costs can be fixed or variable. For the purposes of analyzing an investment in safety, it is often useful to allocate costs that are associated with an issue and spread them out over the period of time. A fixed cost would be the same every year whereas a variable cost might change from year to year. A typical fixed cost could be an annual service contract for advanced diagnostics. A typical variable cost could be in-house maintenance expense, which might increase over time as the equipment wears out. Some companies call indirect costs overhead and come up with a formula that distributes these indirect costs over direct labor hours or tons of material produced. Whether it is direct or indirect, variable or fixed, the most important thing is to identify as many costs as possible and match them as closely as possible to the time period in which they are expected to occur.

Savings

Revenue—in accounting terms, sometimes called turnover or sales—can also represent the savings or additional revenue produced by an investment. Savings for safety investments can be less obvious or less tangible than savings from reducing direct costs such as scrap reduction or reduced production labor. Just as with expenses, it is necessary to estimate the changes in savings over time for investments in safety.

Because the assumptions for improvement in safety are often based on unknown future activities and incidents, statistics such as the probability of an event occurring can be used to estimate savings. For example, the probability of a lost-time accident, according to the International Labour Organization of the United Nations, is on average .003 percent per worker per year. In other cases there are established relationships based on plant data or from research that can be used to estimate savings. As another example, it has been shown that investments in reducing fugitive material typically extend the life of conveyor components 25 to 40 percent.

Just as with costs, it is important to identify as many potential savings and match them as closely as possible with the time period within which they are expected to occur.

Capital Expense

The initial cost, if significant, is often called the capital expense or 'CapEx' value. This capital value includes both the purchase and initial installation costs for the equipment. A piece of equipment that is considered capital is called an asset. Long-term programs that involve almost exclusively labor—like training or the hiring of outside resources to establish a safety culture—can be capitalized but are more typically expensed each year as they occur.

Accounting rules require companies to match expenses with the generated revenue, so capital investments must be spread out over some time frame that represents a reasonable useful life. Most governments set these time frames in their accounting regulations to help even out tax receipts and make it easier to compare financial performance between companies.

Depreciation Expense

To match or spread out the capital cost over the useful life of the equipment, an accounting method called depreciation expense—often just called depreciation—is used. There are different formulas used but the most basic approach is called straight-line depreciation where the capital cost is divided by the useful life in years. The resulting expense is charged each year against the revenue on the profit and loss statement; the decreasing value of the capital equipment is accounted for on the balance sheet by reducing the value each year by the amount of depreciation.

If a piece of equipment has an installed cost of $100,000 and a useful life of 10 years, the annual charge to the profit and loss statement would be $10,000 a year ($100,000 divided by 10 years). On the balance sheet each year the value of the equipment would be reduced that amount until it is fully depreciated. The equipment value listed as an asset would be $100,000 minus the accumulated depreciation, so the value of the asset decreases over time until it reaches zero. The $100,000 piece of equipment would be depreciated by the $10,000 expense each year so the net value of the asset: Year 1: ($100,000 - $10,000 = $90,000), Year 2: ($90,000 - $10,000 = $80,000), and so forth.

Governments, to incentivize investment, often manipulate the rules for capitalization and taxation. For example, if the government determined that it would benefit society if all equipment guarding was upgraded, it could pass a law that says companies can expense guarding in the current year rather than depreciate it over a period of years. The net effect is to lower the taxes paid that year by the company, which is often enough incentive for companies to invest. The government, to justify such a change, may have calculated that there will be fewer people ending up on disability—thus reducing government disability payments and so providing a net benefit to all taxpayers.

Opportunity Cost and Availability

Opportunity cost is the value of production lost due to unscheduled events such as machine breakdowns, shutting down to clean, or safety incidents. The concept is that if the product is not available for processing, and therefore sale, a profit opportunity is lost. The equation is show in **Figure 34.6**.

$$\text{Opportunity Cost} = \frac{\text{tons}}{\text{hour}} \times \text{Unplanned Downtime (hours)} \times \left[\frac{\text{Sales(\$)}}{\text{ton}} - \frac{\text{Cost of Sales(\$)}}{\text{ton}}\right]$$

Figure 34.6.

Calculation for Opportunity Cost.

6

A related concept is availability. Usually expressed as a percentage, availability represents the amount of time that the system (a conveyor, for example) is planned to be available for production compared to the actual time it is. The equation is show in **Figure 34.7**.

Mean time between failures (MTBF) could be any event that causes an unplanned stoppage of the conveyor such as an injury, the need to clean, or a failure of a key component. [The mean time is the number where half of the lengths of time between failures are above that number and half are below. It is a statistical term that is slightly different than the average time between failures.] For the purposes in evaluating investments in safety, mean time between incidents is used interchangeably with mean time between failures in **Figure 34.7**.

Opportunity costs rise when availability is less than 100 percent.

Reliability

Conveyor technology does not develop in a coordinated and incremental fashion but rather in discontinuous steps. Currently, conveyor belts are strong, wide, and fast enough to carry great volumes of bulk materials over great distances. However, many of the components are not able to handle the speeds, wear, impact forces, or fugitive materials generated long enough to avoid unplanned outages. In addition, because of the capital cost of conveyors and the risks to production from making unproven changes, conveyor engineering tends to be conservative and development of new technologies takes decades.

The failure to include reasonable and obtainable targets for conveyor reliability and capacity in the feasibility studies for a project is one of the main reasons conveyor systems are designed with unreasonable expectations and too often fail to reach their design capacity. The plant and its conveyor system have been designed to produce the tonnage required to profitably process the bulk material but not designed for the reliability of the available conveyor equipment.

Examining the reliability equation (**Figure 34.8**) for conveyors requires understanding the probability of failure for all the critical components in the conveyor system. These are the components of which the failure of any one item would cause an unscheduled outage of the system.

The simplest combination of component reliabilities depicted in a linear fashion is called series reliability. If one component fails, then the system fails. As shown in **Figure 34.9**, if a main pulley fails unexpectedly, the conveyor system turns from an available system into an unavailable system.

The maintenance and operation of conveyors is often focused on the main components. This philosophy of operation, as shown in **Figure 34.10**, is common: as long as the cargo is coming off the belt there is no need for an unplanned shutdown to fix issues.

Figure 34.7.

Calculation for Availability.

$$\text{Availability} = \frac{\text{Mean Time Between Failures}}{\text{Mean Time Between Failures + Mean Time to Repair}}$$

Figure 34.8.

Calculation for ReliabilityEquation courtesy of http://reliawiki.com/index.

$$\text{Reliability} = \frac{\text{Mean Time Between Incidents}}{\text{Mean Time to Fail}}$$

Reliability of Systems Working in Series = $R_1 \times R_2 \times R_n \ldots$

Reliability of Systems Working in Parallel = $1 - [(1 - R_1) \times (1 - R_2) \times (1 - R_n) \ldots]$

Where R = Probability of Failure of a System Between Planned Maintenance

http://rliawiki.com/index.php/RBDs_and_Analytical_System_Reliability

But conveyor system reliability is more complicated than a simple series linkage of all the main component's probabilities of failure. **Figure 34.10** shows a parallel reliability graphic where main components are protected by parallel system sensors, and the performance of the entire system has been enhanced by the use of common accessories. But as shown in **Figure 34.11**, the plugged chute sensor has been disconnected due to frequent trips, and the belt cleaners are non-functional. The main system—Drive/Belt/Pulleys/Chute—is still considered operational and production continues. But in this case, plant management is essentially playing the lottery. If their luck holds, production goals will be met, and they can fix problems at the next scheduled outage. But what is the risk they are taking? They are playing roulette with the capital investment and workers' health and safety.

Research has shown that companies that shut down and fix problems as soon as they can and practice advanced maintenance management tend to be 20 to 30 percent safer and 20 to 25 percent more productive.

Net Present Value and Internal Rate of Return

Net present value (NPV) is a financial measurement that is widely used to compare investments of all types. The basic idea is to bring a string of investments and annual costs forward to provide a more accurate comparison of investment alternatives. (**Figure 34.12.**) A form of NPV is life cycle costing where two or more options are evaluated based on initial price, annual costs, and expected life as expressed in terms of today's currency. Generally, the option with the highest NPV would be the wisest choice.

Internal rate of return (IRR) shows the annual compounded rate of return on an investment and is defined as the interest (or discount) rate that makes the NPV equal to zero. (**Figure 34.13.**)

Both NPV and IRR are financial tools that can be used to compare investment options including safety investments.

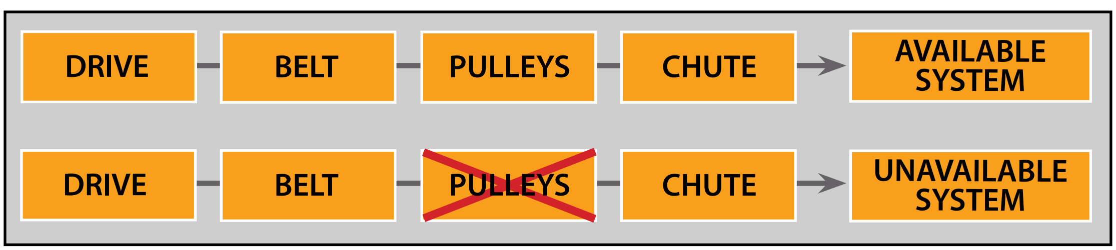


Figure 34.9.

Series Reliability Charts for Major Conveyor Components. Top: All components are operational and the conveyor system is available. Bottom: A failure of a major pulley has made the conveyor unavailable.

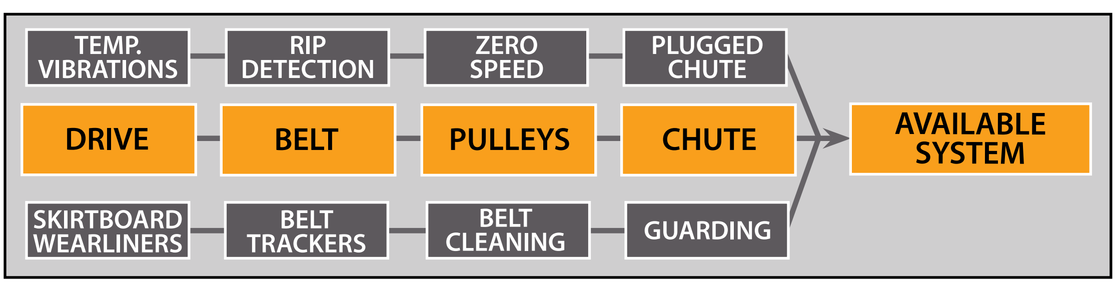


Figure 34.10.

Parallel Reliability in a Conveyor System—A.

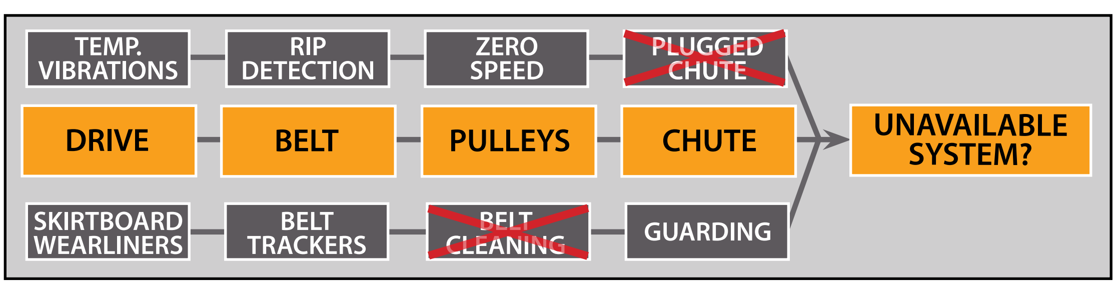


Figure 34.11.

Parallel Reliability in a Conveyor System—B.

Calculating Conveyor System Reliability

The reliability of a system as shown in the following tables is calculated by knowing or estimating the failure rate of each component over the time frame under consideration. For conveyors, a typical time frame is the period between major outages. The goal is for the system to run reliably between major, planned outages.

Assumed Values of Reliability Between Major Outages for Example Calculation

Main Component	Reliability of Components	Sensor Component	Reliability of Sensors	Accessory	Reliability of Accessories
Drive	0.999	Temperature & Vibration	0.985	Skirtboard & Wear Liners	0.875
Belt	0.990	Zero Speed	0.975	Belt Tracker	0.825
Pulleys	0.997	Rip Detection	0.998	Belt Cleaners	0.750
Chute	0.950	Chute Plug	0.925	Guarding	0.800

For the Main Systems in Series, Calculate the Reliability:

$R_{Main\ Systems} = R_{Drive} \times R_{Belt} \times R_{Pulleys} \times R_{Chute} = (0.999) \times (0.990) \times (0.997) \times (0.950) = 0.937.$

In this example, there is a 93.7 percent chance the system will be available based on the Drive, Belt, Pulleys, and Chute performing as required where failure of one of these major components causes the failure of the whole system.

Failure of a Sensor or Accessory will not cause failure of the whole system but can contribute to a lack of reliability for the system.

Calculate the Reliability of the Sensors:

$R_{Sensors} = R_{Temp/Vib} \times R_{Rip} \times R_{Zero} \times R_{Plug} = (0.985) \times (0.975) \times (0.998) \times (0.925) = 0.887$

The Sensors and Accessories are not on critical paths but operate in parallel with the main systems.

Calculate the Reliability of the Accessories:

$R_{Accesories} = R_{Skirt/Liner} \times R_{Tracker} \times R_{Cleaners} \times R_{Guards} = (0.875) \times (0.825) \times (0.750) \times (0.800) = 0.433$

Combine the Reliabilities of the Main System, Sensors, and Accessories to arrive at the reliability or the probability that the conveyor will not have an unscheduled outage before the planned major outage.

To Determine the Reliability of the Conveyor System, Combine the Reliabilities

The Sensors and Accessories are treated as series systems:

$R_{Sensors+Accessories} = R_{Sensors} \times R_{Accessories} = (0.887) \times (0.433) = 0.384$

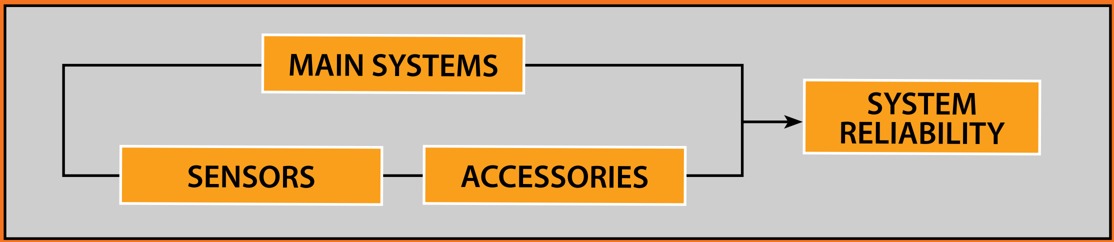
The Sensors and Accessories are combined in parallel with the Main Systems to get the total system reliability:

$R_{Conveyor} = 1- [(1- R_{Main}) \times (1- R_{Sensors+Accessories})] = 1- [(1-0.937) \times (1- 0.384)] = 96.1\%$

Note: If all subsystems could function at a reliability of 99.9 percent between scheduled major outages, the overall reliability of the conveyor would be 99.9 percent.

$R_{99.9} = 1- [(1- 0.937\%) \times (1- 0.992)] = 0.999$ or 99.9% reliable.

This shows that it is important to maintain all systems to achieve optimum reliability.



Combination Series and Parallel Reliability Diagram.

In figures **34.12** and **34.13**:

- Cash Flow = the expected savings for a specific year minus the costs of operating and maintaining the project in that year.
- I = The total number of periods (usually years) used in the analysis.
- Initial Investment = the initial purchase, delivery, and installation costs of the project.
- R = the weighted cost of money for the company from all sources: borrowing, selling stock, and so on. Expressed as a decimal and often called the discount rate. This can also be thought of as the inflation rate.
- IRR = the discount rate that makes the NPV equal to zero.

NPV will allow a company to analyze the total future savings gained over the life of the improvement. The IRR must be found by using trial-and-error to find the rate that makes the NPV equal to zero. IRR will show at what interest rate the investment will break even. If the IRR of a new project exceeds a company's required rate of return, that project may be desirable. If IRR falls below the required rate of return, the project should be rejected.

NPV and IRR can be best used for comparing different investment decisions over the same length of time and discount rates. It is typically recommended to report NPV and IRR in conjunction with each other as there are several limitations to IRR interpretation.

Do not let these seemingly complex formulas deter the calculations. Once past the mathematical notations, the results are pretty easy to understand. Almost all spreadsheet software programs have NPV and IRR functions where the numbers can be plugged in and the computer does the calculations.

Often, buying on price rather than buying on value or life cycle cost results in a negative NPV and IRR, which means these sub-optimal investments actually cost, rather than save, money.

On belt conveyors, a negative NPV is a common result from the investment in components to reduce fugitive materials that are not maintained, or from buying safety equipment that is not used. As a result, the costs for fugitive materials and safety incidents continue, because the systems to control these problems are not an absolute requirement for production. The buying of equipment and not using it, or not maintaining it, costs the company more. The savings from no maintenance expenses or from non-use of a subsystem are phantom savings. The operation suffers a double penalty—paying the initial cost without receiving any benefit.

Unfortunately, it is all too common to make the shortsighted decision to purchase specialized equipment and then depend on in-house maintenance to keep it productive. The reality is, most companies still manage using 'old school' concepts—such as the 'Run till Broke' philosophy—so maintenance budgets have been squeezed—and production schedules

$$\text{Net Present Value} = -\text{ Initial Investment} + \sum_{i=1}^{I} \frac{\text{Annual Cash Flows}}{(1+R)^i}$$

$$\text{NPV} = -\text{ Initial Investment} + \frac{\text{Cash Flow Year 1}}{(1+R)^1} + \frac{\text{Cash Flow Year 2}}{(1+R)^2} + \frac{\text{Cash Flow Year 3}}{(1+R)^3} \ldots$$

Figure 34.12.

Calculation for Net Present Value (NPV).

$$\text{Internal Rate of Return} = \text{What Rate R will Make NPV} = 0?$$

$$0 = -\text{ Initial Investment} + \frac{\text{Cash Flow Year 1}}{(1+\text{IRR})^1} + \frac{\text{Cash Flow Year 2}}{(1+\text{IRR})^2} + \frac{\text{Cash Flow Year 3}}{(1+\text{IRR})^3} \ldots$$

Figure 34.13.

Calculation for Internal Rate of Return (IRR).

expanded—to the point that there are not enough maintenance personnel or downtime hours to maintain all the equipment. As a result, the lack of maintenance and training of maintenance personnel becomes one of the main root causes of accidents.

As they represent long-term investments with less tangible benefits, the systems that promote safety and fugitive material control are not a priority compared to production-related equipment. As a consequence, in-house maintenance departments seldom have the resources to maintain these systems—the very equipment that will improve the workers' long-term health and safety. A survey of Martin Engineering sales and service personnel estimated that less than 20 percent of conveyors are properly outfitted with belt cleaners and other fugitive material control systems—and of those with installed systems—only 25 percent are properly maintained!

Comparing NPV and IRR for Belt Cleaner Systems

Assessment of carryback levels is important to the consideration of belt conveyor safety because it is well established that the more fugitive material generated from belt conveyors, the more labor required around belt conveyors. The more labor around belt conveyors, the greater the chances for accidents and injuries. It is thus readily apparent that improved belt cleaning will minimize safety incidents and allow a plant to provide a **Return on Conveyor Safety™** for its investment in these systems.

It is instructive to compare different options for investing in belt cleaners to reduce cleanup costs. Estimates are based on comparing the investments required to reach several different CEMA Carryback Levels. (**See Using Carryback Level Ratings.**)

All proposed investments use cleaning systems of the same CEMA Application Class. CEMA Belt Cleaner Application classes were established with the publication of *CEMA Standard No. 576 Classification of Applications for Bulk Material Conveyor Belt Cleaning* in 2013. This provides a uniform procedure for determining the severity of application for any individual belt conveyor. After determining the severity of application, a conveyor designer or belt-cleaner buyer would select a cleaning system that matches the application rating. For more information, see *CEMA Publication No. 576*, which is available for free download from the CEMA website, *cemanet.org*.

The life of the belt cleaner main assemblies (mainframes) is 7 years; the discount rate used is 10 percent.

Initial Investment is the price to purchase a belt-cleaning system and the cost (mostly labor) to install said cleaning system.

Annual Cleanup Costs are the costs for labor and equipment to clean fugitive material around the belt conveyor.

Annual Maintenance Costs are the expenses for replacement blades as well as the labor for belt-cleaner inspection and blade replacement.

The numbers used in the example are fictional but realistic; they show that maintaining the status quo is the most expensive option. (**Figure 34.14 and Figure 34.15.**) All options

Figure 34.14.

Summary Data for NPV & IRR Example.

CEMA Carryback Level (g/m²)		Initial Investment ($)	Annual Cleanup Costs ($)	Annual Maintenance Costs ($)	Net Cash Flow ($)
Current State: Level I	>250	1,000	50,000	1,500	-50,000 + 1,500 = -48,500
Future State A: Clean to Level III	10 to 100	5,000	25,000	2,500	-25,000 + 2,500 = -22,500
Future State B: Clean to Level IV	<10	25,000	4,500	3,500	-4,500+3,500 = -1,000

6

result in a negative NPV because not all cleanup expense is eliminated. The IRR is zero because there is no positive return. The annual cash flow can be varied to reflect differences in production or the need for additional maintenance as the equipment ages.

Future State A may be a viable alternative, even with a negative NPV and IRR because of the significantly increased investment required to go from Level III to Level IV cleaning. For example, the decision to make the Level III investment of $5,000 might only require a local (plant-level) decision, but the Level IV investment of $25,000 may require corporate approval. In that case, the decision to pick Future State A is not necessarily a bad one and certainly, from a health and safety standpoint, much better than the current state.

If the comparison was made on a simple ROI without consideration for the time value of money the results would be:

Simple ROI for Future State A
[(50,000- 25,000) + (1500-2500)]/5000 = 24000/5000 = 4.8 or (480%) or 2.5 months payback.

Simple ROI for Future State B
[(50,000- 4,500) + (1,500-3,500)]/25,000 = 43,500/25,000 = 1.74 or (174%) or 6.9 months payback.

The Importance of Measurement

The goal of this analysis is to reduce uncertainty in making decisions so that management can allocate resources to those investments that increase productivity with minimum risk. Uncertainty and risk cannot be reduced to zero so it is important to measure those costs that have a direct bearing on increasing productivity and safety.

There are many excuses raised to avoid measuring less tangible costs. They include: 'It cannot be measured,' 'It is too expensive,' 'It is too time-consuming,' 'It is an invasion of privacy,' 'It will expose confidential information,' 'Statistics lie,' and so on. The book, *How to Measure Anything – Finding the Value of Intangibles in Business*, by D.W. Hubbard, is a valuable reference for those dedicated to improving safety that run into these common management excuses. Usually, only a few things really matter in making a decision on a safety investment, but the information value of those few things usually matters a lot. If it matters, it can be measured. The only valid objection to measurement is if the cost of the measurement exceeds the value of the information in making a safety decision.

Measuring Return on Conveyor Safety™

It can be shown that a clean, well-maintained system is more profitable than a dirty, poorly maintained system.

In addition to a clean environment, it is important to maintain a safe environment. Besides the ethical reasons, there are financial repercussions to safety incidents and accidents. A cleaner environment will lower safety risks. The goal should be to have zero safety incidents, but costs to reach zero must be considered. No amount of money can mitigate every risk, and every business has limited resources to mitigate these risks. However, an invest-

State	Discount Rate R	Initial Investment Year 0	Cash Flow Year 1	Cash Flow Year 2	Cash Flow Year 3	Cash Flow Year 4	Cash Flow Year 5	Cash Flow Year 6	Cash Flow Year 7	NPV	IRR
Current State	10%	1,000	-48,500	-48,500	-48,500	-48,500	-48,500	-48,500	-48,500	(215,562)	0%
Future State A	10%	5,000	-22,500	-22,500	-22,500	-22,500	-22,500	-22,500	-22,500	(104,127)	0%
Future State B	10%	25,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	-1,000	(27,153)	0%

Figure 34.15.

Example calculation for Net Present Value (NPV) and Internal Rate of Return (IRR).

6

Using Carryback Level Ratings to Assess Cleaning Performance of Belt Cleaning Systems

Levels of belt cleaning, used as a goal or as a guide for evaluating the performance of belt cleaning systems, are discussed in the 7th edition of the Conveyor Equipment Manufacturers Association's book, *Belt Conveyors for Bulk Materials*.

In its chapter, "Belt Cleaners and Accessories," the CEMA book explains the use of levels, saying:

> Carryback cannot be completely eliminated so the level of carryback should be based on the requirements of the specific application. For example a conveyor at a port facility may require a very clean belt, Level IV, to minimize carryback falling into the water or because the conveyor conveys multiple materials and contamination cannot be tolerated. In other applications such as open pit mining more carryback can be tolerated, typically Level II, by virtue of the location and design of the transfers where clearing accumulations of carryback can be done with powered equipment and accumulations do not effect [sic] production.

Carryback Level	Carryback Amount, Dry Weight, Mean Value
Level I	> 0.05 lbf/ft2 (250 g/m²)
Level II	> 0.02 to 0.05 lbf/ft² (100 to 250 g/m²)
Level III	> 0.002 to 0.02 lbf/ft² (10 to 100 g/m²)
Level IV	0.0004 to 0.002 lbf/ft² (2 to 10 g/m²)

CEMA Table 11.5 Carryback Levels

The level of cleaner performance (or the amount of carryback remaining on the belt) is determined by actual measurement. *Belt Conveyors for Bulk Materials* notes:

> Belt cleaner manufacturers and some independent consultants can perform carryback testing to establish the performance of a belt cleaner system. While the methodology may vary, it is important to recognize that belt cleaning is a process and therefore several measurements under varying conditions are required to establish a mean value of carryback.

In the book, *FOUNDATIONS™, 4th edition: The Practical Resource for Cleaner, Safer, More Productive Dust and Material Control*, Martin Engineering was the first to propose such a scale. The Martin Engineering version uses Level 0 for the baseline amount of carryback with 'zero' cleaners installed, with the numbering of levels going up with the number of cleaners installed and their efficiency increasing to Level 3. The following is presented as part of Chapter 31 Performance Measurements in *FOUNDATIONS™, 4th edition*:

> An operation's success at eliminating carryback can be categorized into arbitrary "Levels." Achievement of these levels would be determined by a measurement of the amount of carryback remaining on a prescribed area (usually, a square meter) of belting. For the purposes of this discussion, the baseline for carryback material remaining on the belt (or "Level 0" cleaning) would be more than 250 grams of material per square meter.
>
> Level I cleaning would be defined as allowing 101 to 250 grams of carryback per square meter to remain on the belt. A typical belt-cleaning system that could achieve Level I cleaning would be a single primary cleaner or a slab-style secondary cleaner.
>
> Level II cleaning is defined as leaving 11 to 100 grams of material per square meter of belting. A typical system to achieve this level of carryback would be a double or triple engineered cleaning system, composed of a pre-cleaner with a secondary cleaner and sometimes even a tertiary belt cleaner.
>
> Level III cleaning is defined as leaving carryback levels between 0 to 10 grams per square meter. A cleaning system that might achieve this level of performance in typical circumstances would be a belt-washing system involving one or several water-spray bars, multiple cleaning assemblies, and a method of removing excess moisture from the belt. The more complicated or sophisticated systems achieve improved cleaning performance; they also cost more to purchase and maintain.

The book *FOUNDATIONS™, 4th edition* also offers a methodology called the Swinderman Scale for Fugitive Material to evaluate for a conveyor's (or a plant's) performance in belt cleaning, as well as its control of dust and spillage. For greater detail on the Swinderman Scale and its assessments of fugitive material, see the book or visit *martin-eng.com/FOUNDATIONS*.

ment for safety not only assists in material throughput, but also decreases safety incidents.

Projecting Savings from an Investment in Safety

This section provides a model that allows the forecast of the savings due to a safety investment. Most financial models focus on investments in equipment and reduction of direct costs. A comparatively small amount of information exists on the forecasting of an ROI due to an investment in safety.

Safety is not a fixed value. It is important to note that there is a lot of variability in safety-related data. Because of this variability, any model will likely require general estimates be made. In addition to the physical implementation of safety investments, proactive management of assets and the development of a safety culture philosophy are required for an ever-improving safety environment. Any plant can always improve its safety, so a continuous improvement management approach is necessary.

Value of Statistical Life

An important concept that will be used to develop safety investment analysis is the Value of Statistical Life (VSL). VSL is a tool widely used by economists to compare the effects of policies on the costs to society. VSL is defined as the monetary value that a society or group of individuals are willing to pay to reduce the risk of mortality by one statistical death. This should not be confused with the actual value of life—which some would consider to be priceless—or what individuals would be willing to pay to extend their own life.

The Value of Statistical Life changes from industry to industry and even within a country. This topic is the subject of many scholarly papers and much debate. Our interpretation of the 1995 VSL numbers shown in a study, *Variations between Countries in Values of Statistical Life*, by Ted R. Miller, range from $40,000 in Nigeria and Bangladesh, and $4,680,000 in Japan based on 1995 values. For 2016, these VSL figures could be updated to $51,000 and $5,987,000 respectively.

Because of the variations in published data, to use the Value of Statistical life calculations, the best approach is to get agreement on a value from the corporate accounting department or from a relevant industry association. The United States Department of Transportation (US DOT) has done a great deal of detailed work with VSL analysis. The VSL and safety investment model shown here is based on the US DOT program. The first equation to be introduced will be the value of a statistical life for a given year.

The US DOT utilized several studies to determine the 2013 VSL to be $9.2 million in the United States. To account for inflation in future cash flows associated with the VSL, the US DOT proposes adjusting the VSL using **Figure 34.16**.

The VSL has been established for assessing costs associated with deaths. In order to assess injuries that do not result in death, the Abbreviated Injury Scale (AIS) will be used. The AIS associates the 'willingness to pay' values for injuries not resulting in death. The AIS scale has become one of the most widely used anatomic scales for rating severity of injuries.

The AIS scale ranges from 1 for minor injury to 6 for maximum injury or virtually non-survivable and can be matched with statistical occurrences of each category. **Figure 34.17** shows the AIS values with their respective descriptions of their severity and scaling factors. The scaling factors correspond to the fraction of a fatality that each AIS level is associated with. The willingness to pay for each level increases with each increase in AIS level severity.

$$VSL_{2013+n} = VSL_{2013} \times (1+PPI/100)^n$$

n = The number of years since 2013

Where PPI is the Producer Price Index and the VSL is country specific

Figure 34.16.

Calculation for Inflation-Adjusted Value of a Statistical Life (VSL).

6

Various countries and industries report incidents in significantly different ways. The categories vary in name and definition, so they do not always match up with the AIS levels. Injury categories and the probabilities of injuries are as specified in the United Nations International Labour Organization's 2005 publication, *Introductory Report: Decent Work – Safe Work*.

In this study, the AIS scale of 1 to 6 is condensed to represent the common industrial injury reporting classifications of 'No Lost Time,' 'Lost Time,' and 'Fatal.' While the use of actual data and local currency is always better when evaluating investments, the use of these assumptions will give a reasonable estimate of global averages.

Figure 34.18 presents the direct costs of injuries based on a Statistical Value of Life approach from the United States Department of Transportation methodology. Cost estimates from other sources are consistent with these estimates. The cost of injuries in the United States is at the upper end of the cost curve.

Figure 34.19 shows the United Nations' International Labor Organization global average estimates of probabilities for levels of injury and disease. Note that they estimate about as many deaths and disabilities from disease as from accidental death. Work-related disease often takes a long time to manifest itself while the results of accidents are often immediate.

Incident Ratio

There are many different ratios used by various governments to establish an incident rate or ratio. These rates are used by companies to measure safety improvements, by insurance companies to set insurance premiums, and by governments to trigger fines or interventions. From the viewpoint of safety investments, these numbers are useful to indicate improvements in safety programs but are reactive not proactive indicators.

For investments in safety, it is the improvement ratio that is of the most interest. Target rates of improvement can be used in combination with the Value of Statistical Life and the probability of an injury or disease to estimate the amount that can be invested.

For example, if a 25 percent improvement in the incident rate is desired, the probability of each injury class can be reduced the same percent. The difference in the VSL costs provides an indication of the pool of money available for investing.

The reduction in injuries and disease can be estimated from different studies in the literature which have been provided by suppliers based on case studies for their equipment, or simply based on the management-established targets.

Figure 34.17.

Summary of Literature: Employee Cost and Savings for Safety.

AIS Level	VSL Multiplier	Severity
1	0.003	Minor
2	0.047	Moderate
3	0.105	Serious
4	0.266	Severe
5	0.593	Critical
6	1.000	Maximum

Figure 34.18.

Estimates of the Statistical Value of a Life in the United States (U.S. Department of Transportation).

Reporting Category	AIS Injury Scale Factor (Level)	Cost per Incident (VSL2015 = 9.42 million USD)
Fatal Injury	1.000 (AIS #6)	$9,420,000 USD
Lost Time Injury	0.025 (Avg. AIS #2 to #5)	$235,500 USD
No Lost Time Injury	0.003 (AIS #1)	$28,260 USD

Figure 34.19.

Estimates of Global Probabilities of Work-Related Injuries (International Labour Organization).

Probability per Worker (per ILO)			
Work-Related Injuries		Work-Related Diseases	
Fatal	0.015%	Fatal	0.015%
Lost Time	0.075%	Permanent Disability	0.075%
No Lost Time	0.225%	Limited Disability/Lost Time	0.225%

6

Less Tangible Costs

From a safety investment standpoint, any significant cost, which has a bearing on the investment decision, should be measured.

Traditionally accountants are most concerned with direct or more tangible costs. (**See Tangible and Less Tangible Costs.**) That is because the direct costs are easier to measure and are often required to be included in official financial statements. Tracking costs and collection of data which is not directly used for decision-making is a waste of time and an example of indirect costs that do not contribute to making sound safety decisions. It is typical that much more time and effort is spent on useless reports and metrics than on those that actually have an impact on the safety decision-making process.

When making a decision on a safety investment, it important to focus on collecting data and making reasoned estimates of the less tangible, indirect costs, because *OSHA's $afety Pays Program* shows indirect costs can be as much as 4.5 times direct costs. (**Figure 34.20.**)

Projected Safety Savings Methodology

The approach is to:

1. Estimate the annual savings using:
   a. Value of a Statistical Life (VSL).
   b. Probabilities of occurrence (P_{ix}).
   c. Percent reduction in incidents (ΔP_{ix}).
2. Estimate the effects of indirect costs.
3. Estimate the capital and maintenance costs of the investment options.
4. Determine the Return on Investment for 1 year.
5. Calculate the NPV over the life of the investment options. (**Figure 34.21.**)

How Many Options to Consider?

A conveyor is only one part of what is usually a complex assemblage of equipment, structures, information systems, and utilities. Particularly for a completely new mine or processing facility, there are a multitude of interrelated scenarios to consider, each with different ranges of possible outcomes. A common technique for complex decision-making is to use the class of computer simulations broadly called the Monte Carlo method. The Monte Carlo method is an advanced problem-solving technique used to approximate the probability of certain outcomes by running multiple simulations, using random variables. The Monte Carlo simulation furnishes the decision-maker with a range of possible outcomes and the probabilities each outcome will occur for any choice of action. Generally, this method is appropriate where an optimum solution is not obvious and where large number of investment options combine with uncertain variables.

The methods in this chapter are designed for comparing a limited number of investment options related to conveyor cleanliness, safety, and productivity. At a minimum, the current state should be compared to the future state, which means at least two options should be considered.

Not all financial analysis techniques apply to all safety investments, so picking the appropriate

Tangible (Direct) Costs	Less Tangible (Indirect) Cost Multiplier
$0 - $2,999	4.5
$3,000 - $4,999	1.6
$5,000 - $9,999	1.2
$10,000+	1.1

Figure 34.20.

Ratio of Indirect Costs to Direct Costs of Safety Incidents.

$$\text{Annual Savings} = \text{\# of workers} \times \text{VSL} \times [\Delta P_{iFatal} + \Delta P_{iLostTime} + \Delta P_{iNoLostTime}] \times \text{Indirect Cost Multiplier}$$
$$\Delta P_{ix} = \text{Probability of Incident Class} \times \text{\% Reduction in Incidents}$$

Figure 34.21.

Calculation for Projected Annual Savings Potential from Safety Investments.

6

approach is an important first step. Generally, safety investments have a high first-year ROI but without examining the returns over the life of the investment, an investment at the wrong investment level can actually cost more than maintaining the current state. It is good practice to use the NPV approach in comparing at least two options for every safety investment proposal.

It is also useful to examine how sensitive the results are to changes to the input assumptions. This is called Sensitivity Analysis and can be applied rather easily in analyzing safety investments.

If the assumption is that an investment will reduce the accident rate by 25 percent, how sensitive is the investment to changes in this assumption? What happens to the return if the change in accident rate ends up being 15 percent, or 35 percent? It is simple to change the accident rate assumption and run the NPV analysis again.

Sensitivity analysis is a less complex approach than using advanced techniques such as the Monte Carlo method and can be performed by using basic spreadsheet software. One drawback to the simple sensitivity analysis is that other inputs might also be influenced by the change in one variable.

Regardless of the drawbacks, the NPV and sensitivity analysis techniques are useful for the common safety investment comparisons.

CASE STUDY Return On Conveyor Safety™ at a Coal Mine

This case study is based on a 2015 investigation of a coal mining operation in the United States, performed for Martin Engineering by Dr. Antonio Nieto, Ph.D., and graduate student Daniel P. Brown, both of the Department of Energy and Mineral Engineering at Pennsylvania State University.

A coal mine had an average of 14 non-fatal conveyor-related incidents per year. A $350,000 USD investment was made to purchase and install equipment to control fugitive materials and a contract signed to outsource

Figure 34.22.

Data Collected for Return on Conveyor Safety™ Case Study.

Costs/Incidents	Prior to R.O.C.S.™ Investment	R.O.C.S.™ Investment
Maintenance	In House	$100,000/yr.
Cost of Money (Discount Rate)	N/A	4%
Analysis Time Frame	N/A	10 yr.
Incidents	14	3
Conveyors	14 miles (22.6 km)	14 miles (22.6 km)
Transport time face to portal	2 h	2 h
Carrying Idlers	14,783	14,783
Return Idlers	7,392	7,392
Outages Due to Plugged Chutes	5 h/d	0 h/d
Productivity	500 t/h	1,500 t/h
Belt Beaks	4/mo.	1/yr.
Drive/Belt Slips	2 hr./wk.	0 hr./wk.
Sales Price of Coal	$45/t	$45/t
Labor Force	30	30
Labor Cost: Wages + Benefits	$75/h	$75/h
Exposure to MSD Hazards	1 h/d	2 h/yr.
Exposure to Electrical Hazards	2 h/wk.	1 h/wk.
Culture	Production	Safety

maintenance of these systems. The goal was to decrease the number of annual incidents to 3 per year.

Adopting the philosophy that 'a safe mine is a productive mine,' safety became a focal point for operations. This premise implies that focusing on safety will improve production, and hence results.

As with many investments, the financial analysis could take many paths. The availability of data in this case is superior to what is normally found in the field and so allows several different analyses. **(Figure 34.22.)** Some of the data is included for reference and to indicate the extent of the operation. Some Return on Conveyor Safety™ effects, such as an increase in idler life, were not considered.

Assumptions for Case Study

Some assumptions have to be made to complete the case study financial analysis.

- There was no data on Planned Operating Hours, so an assumption of the planned production schedule will be 24 hours a day, 5 days a week for 50 weeks or 6,000 hours.
- There was no information on Scheduled Outages for major repair, so the reliability calculation will assume two one-week shutdowns annually or 25 weeks between planned major repair outages.
- There was no data on the corporate goal for Availability, so the calculation example is made based on what information is available on lost production of an average five hours per day due to chute plugging.
- There was not a breakdown of the injury incident rates or reductions, so the Annual Savings calculation will use the UN International Labor Organization probabilities per worker.
- The average Sales Value of coal at \$45 per ton is based on internet research for this time frame.
- There was no information on the Cost of Sales, so the ROI and Opportunity Cost calculations will assume a Cost of Sales of \$40 for a gross profit per ton of \$5.
- A Discount Rate of 4 percent is assumed.

The First Year is often used to provide an initial rough estimate to determine if the project warrants further data collection and financial analysis. Except for small short-term investments, a one-year ROI is not a particularly accurate method for evaluating investments. (**Figure 34.23.**)

Other useful calculations are shown in **Figures 34.24 through 34.31**.

Financial Analysis

Financial results are summarized in **Figure 34.32**. To illustrate all the calculations available, several different results are presented.

$$\text{Equation 1: ROI} = \frac{\text{Total Savings}}{\text{Total Costs}} \qquad \text{ROI} \times 100 = \text{ROI\%} \qquad \frac{1}{\text{ROI}} = \text{Years to Payback}$$

$$\text{ROI} = \frac{\text{Additional Tons Produced Annually(t)} \times \left[\text{Sales Price}\left(\frac{\$}{t}\right) - \text{Cost of Sales}\left(\frac{\$}{t}\right)\right]}{\text{Equipment Investment (\$)} + \text{Annual Maintenance Costs (\$)}}$$

$$\text{ROI} = \frac{\left(1{,}500\,\frac{t}{h} - 500\,\frac{t}{h}\right) \times 6{,}000(h) \times 5\,\frac{\$}{t}}{\$350{,}000 + \$100{,}000} = \frac{\$270{,}000{,}000}{\$450{,}000} = 66.7$$

$$\text{ROI\%} = 66.7 \times 100 = 6{,}670\% \quad \text{and} \quad \text{ROI}_{years} = \frac{1}{66.67} = 0.015 \text{ years} = 5.4 \text{ days}$$

Figure 34.23.

Calculation for First Year Return on Investment: Return on Conveyor Safety™ Case Study.

Figure 34.24.

Calculation for Opportunity Cost: Return on Conveyor Safety™ Case Study.

$$\text{Equation 2: Opportunity Cost} = \frac{\text{tons}}{\text{hour}} \times \text{downtime(hours)} \times \left[\text{Sales}\left(\frac{\$}{\text{ton}}\right) - \text{Cost of Sales}\left(\frac{\$}{\text{ton}}\right)\right]$$

$$\text{Opportunity Cost} = 500\left(\frac{\text{t}}{\text{h}}\right) \times 5\left(\frac{\text{h}}{\text{day}}\right) \times 5\left(\frac{\text{days}}{\text{week}}\right) \times 50 \text{ weeks} \times 5\left(\frac{\$}{\text{t}}\right) = \$625{,}000$$

Figure 34.25.

Calculation for Availability: Return on Conveyor Safety™ Case Study.

$$\text{Equation 3: Availability} = \frac{\text{Mean Time Between Failures}}{\text{Mean Time Between Failures} + \text{Mean Time to Repair}}$$

$$\text{Availability} = \frac{\text{Actual Daily Production(h)}}{\text{Planned Production(h)}} = \frac{24\text{(h)} - 5\text{(h)}}{24\text{(h)}} = \frac{19\text{(h)}}{24\text{(h)}} = 0.79 = 79\%$$

Figure 34.26.

Calculation for Reliability: Return on Conveyor Safety™ Case Study.

$$\text{Equation 4: Reliability} = \frac{\text{Mean Time Between Incidents}}{\text{Mean Time to Fail}}$$

$$\text{Reliability} = \frac{\text{Mean Time Between Incidents}}{\text{Mean Time to Fail}} = \frac{(24\text{h} - 5\text{h})}{25 \text{ weeks} \times 5 \frac{\text{days}}{\text{week}} \times 24\left(\frac{\text{h}}{\text{d}}\right)}$$

$$\text{Reliability} = \frac{19\text{h}}{3{,}000\text{h}} = 0.006 \quad \text{Reliability} = 0.006 \times 100 = 0.6\%$$

Figure 34.27.

Calculation for Value of a Statistical Life: Return on Conveyor Safety™ Case Study.

$$\text{Equation 7: } VSL_{2013+n} = VSL_{2013} \times 1.0118^{n}$$

$$VSL_{2015} = VSL_{2013} \times 1.0118^{2} = \$9{,}420{,}000$$

Figure 34.28.

Calculation for Annual Savings from Reduced Injuries: Return on Conveyor Safety™ Case Study.

$$\text{Equation 8: Annual Savings} = \#\text{ of Workers} \times VSL \times [\Delta P_{iFatal} + \Delta P_{iLostTime} + \Delta P_{iNoLostTime}] \times \text{Indirect Cost Multiplier}$$

$$\Delta P_{ix} = \text{Probability of Incident Class} \times \text{Reduction in Incidents}$$

$$\Delta P_{ix} = \text{Probability of Incident Class} \times \text{Reduction in Incidents} = 0.015\% \times \left(1 - \frac{3}{14}\right) = 0.0118\%$$

$$\Delta P_{ix} = \text{Probability of Incident Class} \times \text{Reduction in Incidents} = 0.075\% \times \left(1 - \frac{3}{14}\right) = 0.0589\%$$

$$\Delta P_{ix} = \text{Probability of Incident Class} \times \text{Reduction in Incidents} = 0.225\% \times \left(1 - \frac{3}{14}\right) = 0.1768\%$$

$$\text{Annual Savings} = 30 \times \$9{,}420{,}000 \times \frac{[0.0118\% + 0.0589\% + 0.1768\%]}{100\%} \times 1.1 = \$769{,}379$$

Figure 34.29.

Calculation for Net Present Value: Return on Conveyor Safety™ Case Study.

$$\text{Equation 5: Net Present Value} = -\text{Initial Investment} + \sum_{i=1}^{10} \frac{\text{Annual Cash Flows}}{(1 + R)^{i}}$$

$$NPV = -\$350{,}000 + \sum_{i=1}^{10} \frac{\$769{,}379 - \$100{,}000}{(1 + 0.4)^{10}} = -\$350{,}000 + \$643{,}118 = \$293{,}118$$

Conservatively, the investment produced an ROI of 65 percent, reduced injuries, and increased production.

Note: The IRR result of 191 percent should be used when comparing related investment options and not seen as a possible ROI.

At first it may seem that results conflict or that one result must be correct and the others in error. All the results are valid; pick the best analysis method for the investment, depending upon the available data and corporate financial sophistication.

Less Tangible Benefits

In addition to the financial benefits, this safety investment and change in culture at this mine improved many facets of the operation.

Before any safety culture implementation and investment, the mine was unable to continuously sustain its prep plant with feed material and orders were being missed. Because the operation's focus was on cost-cutting, no money was being spent on the belt conveyor system.

One of the new implementations was a card program that enabled employees to write and submit pertinent observations they felt would improve safety or benefit the mine's operation. The cards were evaluated daily to identify and rank daily and monthly trends. Through the use of this card system, a goal was adopted to lessen the exposure to identified potential accidents. Issues were fixed and changes were made by focusing on trends related to unsafe practices. Several key issues were identified—including prematurely broken, damaged, or worn components, chute blockages, belt/drive slips, and belt breakages. Even issues such as clearing entries for new escape routes, improving stairways, and salting walkways during the winter were addressed and improved.

These investments provided improvements including an increase in availability, an increase in production, and a decrease in accidents. Since this investment, the company has not experienced a lost-time accident.

$$\text{Equation 6: } 0 = -\text{Initial Investment} + \sum_{i=1}^{l} \frac{\text{Annual Cash Flow}}{(1 + \text{IRR})^i}$$

$$0 = -\$350{,}000 + \sum_{i=1}^{10} \frac{\$669{,}379}{(1 + 1.91)^{10}} \qquad \text{IRR} = 191\%$$

Figure 34.30.

Calculation for Internal Rate of Return: Return on Conveyor Safety™ Case Study.

$$\text{ROS} = \frac{\text{NPV}_{\text{Safety}}}{\text{Cost}} = \frac{\$293{,}118}{\$350{,}000 + \$100{,}000} = \frac{1}{0.65} = 1.54 \text{ years}$$

Figure 34.31.

Calculation for Return on Investment Based on Return on Conveyor Safety™ Case Study.

Analysis Method	Before Safety Investment	After Safety Investment
Return on Investment (ROI) First Year	N/A	5.4 days
Opportunity Cost (per year)	$625,000	$0
Availability	79%	100%
Reliability	0.6%	100%
Value of a Statistical Life	$9,420,000	$9,420,000
Savings from Reduced Injuries (per year)	N/A	$769,379/year
Net Present Value (NPV) based on VSL	N/A	$293,118
Internal Rate of Return (IRR)	N/A	191%
ROI based on Return on Conveyor Safety™	N/A	1.54 years

Figure 34.32.

Summary of results: Return on Conveyor Safety™ Case Study.

The analysis does not show the added sales and profits made, even while there was a prolonged depression in the market price of steam coal. These sales and profits—and the production that created them—were made possible by the lack of accidents.

These results clearly demonstrate the positive effects of a small investment in safety—the **Return on Conveyor Safety™**.

CLOSING THOUGHTS
Calculating the Payback for Safety

By utilizing the accounting methods shown here to carefully give value to the intangible benefits created by investments in safety, plant personnel—whether responsible for accounting, production, or safety—can justify conveyor systems and investments that improve workplace safety, and demonstrate the value of systems that make conveyors cleaner, safer, and more productive.

Chapter 34 Appendix

Literature Search for Values

This appendix presents the sources which provided the cost data incorporated into Chapter 34.

A1. Cost of a Fatality
A2. Cost of a Lost-Time Incident
A3. Cost of a First Aid Incident
A4. Cost of Industrial Diseases
A5. Cost of an Enterprise-Wide Safety Incident
A6. Indirect vs. Direct Costs
A7. Return on Investment in Safety Programs
A8. Safety Benefits on Productivity
A9. Benefits from Control of Fugitive Materials
A10. Benefits from Extending Life of Various Conveyor Components
A11. Probability of Accidents
A12. Cost of Downtown
A13. Savings in Insurance due to Safety Programs
A14. Improvements in Financial Results (as Increase in Share Price)
A15. Benefits of Prevention through Design (Design for Safety)
A16. Costs due to Regulatory Citations (USA)

A1. Cost of a Fatality

$991,027	Average costs of fatal injury (CDC estimate)	As cited in Morrison, Kyle W., "The ROI of safety," *Safety+Health*, the Official Magazine of the NSC Congress & Expo, May, 2014. From NSC Injury Facts, 2014
$1,420,000	Average fatality's cost to society (NSC model)	As cited in Morrison, Kyle W., "The ROI of safety," *Safety+Health*, the Official Magazine of the NSC Congress & Expo, May, 2014. From NSC Injury Facts, 2014
$1,450,000	Death, with employer costs, from Average Economic Cost by Class and Severity, 2013 (Table) (page 2)	*NSC Estimating the costs of Unintentional Injuries*, National Safety Council, Itasca, IL 20150
$1,390.000	Cost per death/ Work Injury Costs, (page 62)	*Injury Facts 2013 Edition*. National Safety Council, Itasca, IL, 2013, *www.ncs.org*
$2,992,532	Accident-related deaths	Lebeau, Martin, Patrice Duguay, Alexandre Boucher; *Estimating the Costs of Occupational Injuries, A Feasibility Study in the Mining Industry*, Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST), Quebec, 2013. (page 39) Table 5.3 Cost of occupational injuries in the mining industry by type of injury, Quebec, 2005-2007
$1,020,000	Cost of Fatality	Chai, D.N., and J.J. Hamilton, "Trends in Mining Accidents and Their Costs (1975-1984)," Bureau of Mines, Pittsburgh, PA 1986, *Journal of Safety Research*, Summer 1987, page 96
$ 55,595	Average Medical Costs per Injury (Fatal Injuries). From Table 1: Estimated Number and Medical Costs of Nonfatal and Fatal Occupational Injuries, 2007	Leigh, J. Paul, "Economic Burden of Occupational Injury and Illness in the United States" *The Milbank Quarterly*, Vol. 89, No. 4 (December 2011), pp. 728-772
$8,700,000	Fatality, Mishap Injury Cost Standards Table for use in FY15	FY 2015 Updated Cost per Injury Type Estimate Table, US Army Combat Readiness/Safety Center, injury_Cost_Table_25Sept 14.pdf Available at *https://safety.army.mil/Portals/0/Documents/REPORTINGANDINVESTIGATION/REGULATIONS-GUIDANCE/Standard/Injury_Cost_Table_25Sep14.pdf*
$2,992,532 CAN	Cost of accident-related death, Average cost per case	Lebeau, Martin, Patrice Duguay, Alexandre Boucher; *Estimating the Costs of Occupational Injuries, A Feasibility Study in the Mining Industry*, Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST), Quebec, 2013. (page 39) Table 5.3 Cost of occupational injuries in the mining industry by type of injury, Quebec, 2005-2007
$1,246,800 AUS	Injury Unit cost / fatality. Table 2.4 Unit costs ($ per incident) and total costs ($ million) of work-related injury and illness by severity and nature, 2005-06 (page 26)	*The cost of Work-related Injury and Illness for Australian Employers, Workers and the Community, 2005-06*, Australia Safety and Compensation Council, March 2009
$2,200,000 AUS	Fatality, from Table 2.4 Unit costs ($ per incident) and total costs ($ million) of work-related injury and illness by severity and nature, 2012-13 (page 33)	*The cost of Work-related Injury and Illness for Australian employers, workers and the community, 2012-13*. Safe Work Australia, Canberra, November 2015
1,200,000 RMB (~$153,000 USD)	Compensation to family plus fine to local government	Jianjun, Tu, "Coal Mining Safety: China's Achilles' Heel," *China Security*, World Security Institute, Vol 3 No 2, Spring 2007, pp. 36 - 53

Notes

Currency conversion
1,200,000 RMB @ 0.15 x = $180,000 USD.
AUD = .72 USD: 0.72 x 1,246,800 = 897,696 USD.
CAN = .72 USD: 2992532 x 0.72 = 2,154,632 USD.
Average of all = 1,867,661.

Suggestion

Use $56,000 as minimum.
Maximum $8,700,000; assuming this is both direct and indirect costs.
Average (without 8.7 million) = 1,013,619.
Use $1,000,000 as Average; $2,150,000 as maximum.

A2. Cost of a Lost-Time Incident

Lost-Time usually defined as 3 or more days off work.

$36,592	Average medical cost of lost-time claims	Smith, Danny, "The Other Side of the Coin," *Occupational Health and Safety*, April 2015 (citing the National Council on Compensation Insurance)
$61,000	Disabling injury, Work injury with employer costs, from Average Economic Cost by Class and Severity, 2013 (Table)	*Estimating the costs of Unintentional Injuries, 2013*, National Safety Council, Itasca IL April 2015, page 2.
$53,000	Disabling Injury, Work Injury, with employer costs, from Average Economic Cost by Class and severity, 2012.	"NSC Estimating the costs of Unintentional Injuries-2012," National Safety Council, Itasca, IL, February, 2014.pdf.
$37,000	"Cost per Medically consulted Injury" includes estimates of wage losses, medical expenses, administrative expenses and employer costs	*Injury Facts 2013 Edition*, National Safety Council, Itasca IL 2013, page 62
$237,000	Cost of Permanent Disability	Chai, D.N., and J.J. Hamilton, "Trends in Mining Accidents and Their Costs (1975-1984), "Bureau of Mines, Pittsburgh, PA 1986, *Journal of Safety Research*, Summer 1987, page 96.
$681,615	Average medical Costs per Injury: Permanent Total Disability	Leigh, J. Paul, "Economic Burden of Occupational Injury and Illness in the United States" *The Milbank Quarterly*, Vol. 89, No. 4 (December 2011), pp. 728-772.
$8,046	Average medical Costs per Injury: Temporary Total Disability	
$49,925	Average medical Costs per Injury: Permanent Partial Disability	
	All from Table 1 Estimated Number and Medical Costs of Nonfatal and Fatal Occupational Injuries, 2007.	
$1,100,000	Cost per Injury/Permanent Total Disability Injury (Civilian Employees)	FY 2015 Updated Cost per Injury Type Estimate Table, US Army Combat Readiness /Safety Center, injury_Cost_Table_25Sept 14.pdf *Available at https://safety.army.mil/Portals/0/Documents/REPORTINGANDINVESTIGATION/REGULATIONSGUIDANCE/Standard/Injury_Cost_Table_25Sep14.pdf*
$762,000	Cost per Injury/Permanent Partial Disability Injury (Civilian Employees)	
$26,100	Cost per Injury/3 days Hospitalized @ $8,700/day (Civilian Employee)	
$7,200	Cost per Injury/3 days lost work @ $2,400/day (Civilian Employee)	
	All from Mishap Injury Cost Standards Table for use in FY15	
$25,900 AUD	Injury Unit cost/Long absence	*The Cost of Work-related Injury and Illness for Australian Employers, Workers and the Community, 2005-06*, Australia Safety and Compensation Council, March 2009. 2005-06 ISBN 978 0 642 328 01 4 PDF
$347,300 AUD	Injury cost Partial incapacity	
$1,345,700 AUD	Injury cost/Full incapacity	
	All from Table 2.4 Unit costs ($ per incident) and total costs ($ million) of work-related injury and illness by severity and nature, 2005-06 (page 26)	
$36,200 AUD	Injury Unit cost/Long absence	*The Cost of Work-related Injury and Illness for Australian Employers, Workers and the Community, 2012-13*. Safe Work Australia, Canberra, November 2015.
$808,820 AUD	Injury cost Partial incapacity	
$4,000,000 AUD	Injury cost/Full incapacity	
	All from Table 2.4 Unit costs ($ per incident) and total costs ($ million) of work-related injury and illness by severity and nature, 2012-13 (page 33)	

Notes

Lost-Time usually defined as 3 or more days off work.
Currency conversion
25,900 AUD x .72 = /$18,648 USD

Suggestion

Use $8,000 as the minimum (2011 vs 1986 data).
Use $680,000 as the maximum (assuming $762,000 probably includes indirect costs).
Average without permanent disability = $18,657; use $20,000.

A3. Cost of a First Aid Incident

$935	Average Medical Costs per Injury: Injuries with no days away from work and Injuries with 1 to 4 days away from work. From Table 1 Estimated Number and Medical Costs of Nonfatal and Fatal Occupational Injuries, 2007.	Leigh, J. Paul, "Economic Burden of Occupational Injury and Illness in the United States," *The Milbank Quarterly*, Vol 89. No.4, December 2011, pp 728-772.
$1,300	No Lost Time per Injury From table "Mishap Injury Cost Standards Table for use in FY15"	FY 2015 Updated Cost per Injury Type Estimate Table, US Army Combat Readiness/Safety Center, injury_Cost_Table_25Sept14.pdf Available at *https://safety.army.mil/Portals/0/Documents/REPORTIN-GANDINVESTIGATION/REGULATIONSGUIDANCE/Standard/Injury_Cost_Table_25Sep14.pdf*
$3,100 AUD	Injury Unit cost/Short absence from Table 2.4 Unit costs ($ per incident) and total costs ($ million) of work-related injury and illness by severity and nature, 2005-06 (page 26)	*The cost of Work-related Injury and Illness for Australian Employers, Workers and the Community, 2005-06*, Australia Safety and Compensation Council, March 2009. 2005-06 ISBN 978 0 642 328 01 4 PDF
#4,180 AUD	Injury Unit cost/short absence From Table 2.4 Unit costs ($ per incident) and total costs ($ million) of work-related injury and illness by severity and nature, 2012-13 (page 33)	*The cost of work-related injury and illness for Australian employers, workers and the community, 2012-13*. Safe Work Australia, Canberra, November, 2015

Notes

Currency conversion
$3,100 AUD = .72 x $3100 =2,232 USD

Suggestion

Average without $7,000 = $1,452.
Use $900 as minimum, $1450 as average, and $2200 as maximum.

6

A4. Cost of Industrial Diseases

$4,100 AUD	Disease Short absense	*The Cost Of Work-Related Injury and Illness for Australian Employers, Workers and the Community: 2005-06*, Australian Safety and Compensation Council, Commonwealth of Australia, March, 2009. ISBN 978 0 642 328 01 4 PDF, Table 2.4 (Fatal) page 26
$27,600 AUD	Disease Long absense	
$295,000 AUD	Disease Partial incapacity	
$1,184,00 AUD	Disease Full incapacity	
$615,400 AUD	Disease Fatality	
	Unit cost ($ per incident)	
$301,556 CAN	Occupational disease	Lebeau, Martin, Patrice Duguay, Alexandre Boucher; *Estimating the Costs of Occupational Injuries, A Feasibility Study in the Mining Industry*, Institut de echerché Robert-Sauvé en santé et en sécurité du travail (IRSST), Quebec, 2013. (page 39) Table 5.3 Cost of occupational injuries in the mining industry by type of injury, Quebec, 2005-2007
$1,357,417 CAN	Disease-related deaths	
	Average cost per case	

Notes

Currency conversion
$3,100 AUD = .72 x $3100 =$2,232 USD

Suggestions

Minimum = $6,851; use $7,000.
Maximum use $1,700,000.
Average =$19,922 USD; use $20,000.

A5. Cost of an Enterprise-Wide Safety Incident (Disaster)

Amount	**Incident** (All incidents in USA)
$602,900,000	Upper Big Branch Mine—2010—explosion & fire—29 fatalities.
$56,000,000*	Massey as a result of Upper Big Branch Mine Accident (largest MSHA fine in history: $10,825,368) $209,000,000 settlement.
$1,800,000	Crandall Canyon—2007—collapse—9 fatalities (six miners plus three rescue workers). $1.340,000 fine plus $300,000 for other violations.
$4,200,000	Aracoma Alma Mine—2006 —fire—2 fatalities. $2,500,000 criminal fine plus $1.7 million in civil fines.
$342,000 in fines	Darby Mine No. 1—2006—explosion—5 fatalities.

Notes

*EBITDA loss
Average = 329,450,000

Suggestion

Use $300,000,000 as average; $600,000,000 as maximum.

A6. Indirect vs. Direct Costs (of Safety)

4:1	Indirect costs not covered by Workman's Compensation Insurance	Leigh, J. Paul, "Economic Burden of Occupational Injury and Illness in the United States," *The Milbank Quarterly*, Vol 89. No.4, December 2011, pp 728-772
5:1	Head Pulley Failure Case Study	Roberts, Alan W., "Conveyor System Maintenance and Reliability," *ACARP Project C3018 Final Report*, Australian Coal Industry's Research Program (ACARP), November 1996, acarp.com.au
4.5:1	Splice Failure Case Study	
From a high of 20 to 1 to a low of 1 to 1	"Studies show that the ratio of indirect costs to direct costs varies widely, from a high of 20:1 to a low of 1:1. OSHA's approach is shown here and says that the lower the direct costs of an accident, the higher the ratio of indirect to direct costs."	"Costs of Accidents" from *Safety & Health Management Systems eTool*, Department of Labor, Occupational Health and Safety Administration, US Department of Labor, Washington DC, Available at https://www.osha.gov/SLTC/etools/safetyhealth/mod1_costs.html OSHA cites: Business Roundtable, *Improving Construction Safety Performance: A Construction Industry Cost Effectiveness Project Report*, Report A-3, January, 1982.
4-6:1	OSHA's Office of Regulatory Analysis has stated: "… Our evidence suggests that companies that implement effective safety and health cans expect reductions of 20% or greater in their injury and illness rates and a return of $4 to $6 for every $1 invested…"	OSHA's Office of Regulatory Analysis, as cited in "White Paper The Return On Investment For Safety, Health, And Environmental (SH&E) Management Programs," ASSE Board Of Directors June 8, 2002. Available at http://www.asse.org/bosc-article-6/
Indirect costs may be 'up to 20 times direct costs'	Indirect costs of injuries may be 20 times the direct costs—Indirect costs include: training and compensating replacement workers; repairing damaged property; accident investigation and implementation of corrective action; scheduling delays and lost productivity; administrative expense; low employee morale and increased absenteeism; poor customer and community relations."	Smith, Lee, "Do You Know How Much Accidents Are Really Cutting Your Business" Colorado State University Health & Safety Consultation Program, 1996, as cited in "White Paper The Return On Investment For Safety, Health, And Environmental (SH&E) Management Programs," ASSE Board Of Directors, June 8, 2002 Available at http://www.asse.org/bosc-article-6/
Ratio of uninsured costs to insured costs was typically between 8 and 36 to 1	"The question of quantifying the costs of accidents was addressed in the March 1994 edition of Quarry Management. Using data from five case studies of companies with a total of over 6,000 accidents, it was found that the ratio of uninsured costs arising from accidents (for example, product and material damage, legal costs, emergency supplies, temporary labor, management time and fines) to insured costs (to cover injury, ill health and damage) was typically between 8 and 36:1."	*Mining Annual Review-1995*, a supplement to *Mining Journal*, London England (now owned by Aspermont, Perth, Australia)
2.12:1	Page 38, "The average estimated ratio of direct costs to indirect costs associated with occupational injuries was $2.12 with a standard deviation (SD) of 1.9. This means that for every dollar spent on direct costs, participants believed about $2.12 would be spent on indirect costs.…" (Figure 1, page 42.)	Huang, Yueng-Hsiang, et. al., "Financial Decision Makers' Views on Safety," *Professional Safety*, (ASSE), April, 2009

Notes

Minimum = 1.1:1. Maximum (without 20:1) = 8:1.
Average (w/o 3% & 20:1) = 3.74:1

Suggestion

Use 3.8:1.

A7. Return on Investment in Safety Programs

$8 for every $1 invested	"A SH&E Director for an environmental services company in Massachusetts reported that its tracking data indicated $8 saved for each dollar spent on a quality SH&E program."	From an article by Adele L. Abrams, Safety Management Programs Make Dollars and Sense, ASSE Management Practice Specialty Newsletter, *The Compass*, Volume Number 2, Winter 2001-2002, as cited in "White Paper The Return On Investment For Safety, Health, And Environmental (SH&E) Management Programs," ASSE Board Of Directors, June 8, 2002 Available at http://www.asse.org/bosc-article-6/
ROI of 441% $4.41 (per dollar invested)	Page 39, "…it is clear that the participants believed that the money spent on improving workplace safety would have significant returns. The average perceived return on safety investments was $4.41 (SD = 12.0)."	Huang, Yueng-Hsiang, et. al., "Financial Decision Makers' Views on Safety," *Professional Safety*, (ASSE), April, 2009
ROI of 200% to 441% RTS	From Page 38 "Participants perceived that, on average, for every dollar spent improving workplace safety, about $4.41 (SD = 12.0) would be returned. The median was $2" (Figure 2, p. 42).	
ROI of 400% to 600%	"OSHA (2007) asserts from its own evidence that companies implementing effective safety and health programs can reduce injury and illness rates by 20% or more—and generate a return of $4 to $6 for every $1 invested."	Citing *Safety and Health Management Systems eTool*: Module 1–Safety and Health Payoffs, Helpful Statistics. Occupational Health and Safety Administration,: U.S. Department of Labor, Washington, DC, Retrieved from http://www.osha.gov/SLTC/etools/safetyhealth/helpfulstatistics.html.
400 to 600%	"Studies have shown a $4 to $6 return for every dollar invested in safety and health."	OSHA. (2007). *Safety and Health Management Systems eTool*: Module 1–Safety and Health Payoffs / Helpful Statistics. Washington, DC Occupational Health and Safety Administration, U.S. Department of Labor, Washington DC, Retrieved from http://www.osha.gov/SLTC/etools/safetyhealth/helpfulstatistics.html. https://www.osha.gov/SLTC/etools/safetyhealth/helpfulstatistics.html
220%	"Return on Prevention of 2.2 (This means for every 1 EUR (or any other currency per employee per year invested in workplace prevention, companies can expect a potential economic return of 2.20 EUR. (Or any other currency)."	*The return on prevention: Calculating the costs and benefits of investments in occupational safety and health in companies—Summary of results*, International Social Security Association (ISSA), Geneva, 2011. Page 7
From 3 to 10 dollars saving for every $1 invested (Payback from 300 to 1,000 percent.)	"According to the Vermont Department of Labor, employers can save anywhere from $3 to $10 for every $1 invested in workplace safety—much of that due to workers' compensation savings."	Cited in Smith, Danny, "The Other Side of the Coin," *Occupational Health and Safety*, April 2015. Available at https://ohsonline.com/Articles/2015/04/01/The-Other-Side-of-the-Coin.aspx
35%	Measuring the Relationship between Safety and Safety Culture	Stuewe, David, *Safety Climate: The Role of Leadership in Enhancing Workplace Safety*, IWH Nachemson Memorial Lecture, Toronto, Oct 30, 2007 (extrapolated from Slides 24 and 25). Available from https://www.iwh.on.ca/system/files/documents/nach_2007_steuwe_slides.pdf
50%	Increased supervisor safety talks reduces unsafe acts (Average of Examples A, B, and C, as interpreted/extracted from Figures 1b, 2, 3 & 4)	Zohar, Dov, and Gil Luria, "The Use of Supervisory Practices as Leverage to Improve Safety Behavior: A Cross-Level Intervention Model," Journal of Safety Research, Vol. 34, No. 5, 2003, pp. 567-577. http://dx.doi.org/10.1016/j.jsr.2003.05.006
30%	"Internal rate of return on 10-year safety program to reduce incidents by half … "	Steward, D.A., and A.S. Townsend "There Is More To 'Health And Safety Is Good Business' Than Avoiding Unplanned Costs?" (Foster Wheeler Study) Available from: http://www.behavioral-safety.com/articles/There_is_more_to_safety_than_avoiding_unplanned_costs.pdf
	"As an indication of the potential cost benefit, a conservative 1% improvement in productivity was attributed to safety. This increased the internal rate of return from 7% to 30%."	Page 6 bottom (meat packing company)

A7. Return on Investment in Safety Programs (continued)

10%	"This shows that halving injury frequency is associated with a 10% increase in productivity (Fig 1)."	Page 3 (Foster Wheeler records)
15%	"Halving injury frequency rates was associated with a 15% improvement in productivity."	Page 3 (a single petrochemical site within the European Union)
12%	… the productivity increase associated with a halving of injury frequency rates is in the order of 12%."	Page 5 (two construction studies: Foster Wheeler and single petrochemical site in EU)
(300+%) $3 (or more) for every $1 invested	"Ninety five percent of business executives report that workplace safety has a positive impact on a company's financial performance. Of these executives, 61 percent believe their companies receive a return on investment of $3 or more for each $1 they invest in improving workplace safety."	Findings of The Executive Survey of Workplace Safety, announced by Liberty Mutual Group as cited in Huang et al "Financial Decision Makers' Views on Safety" Liberty Mutual (2001) news release: "A Majority of U.S. Business Report Workplace Safety Delivers a Return on Investment." Available at http://www.larsafe.com/pdfs/Liberty-Mutual-Survey.pdf, also noted in "Executives Believe Workplace Safety Worth Investment" Sept 6, 2001, on ehstoday.com, available at http://ehstoday.com/news/ehs_imp_34706
144.5% ROI	"Net Benefit of Prevention" from "Prevention Balance Sheet (Safety and Health Benefits per Employee per Year MINUS Safety & Health Costs per Employee per Year) = 1.445"	*Calculating the International Return on Prevention for Companies: Costs and Benefits of Investments in Occupational Safety and Health*, Report 1/2013e, published by German Social Accident Insurance, (Deutsche Gesetzliche Unfallversicherung) [DGUV], Berlin, February 2013, "Prevention Balance Sheet," page 32.
2.2 Mean Benefit-Cost Radio (Return on Prevention	"Expenditure on occupational safety and health is an investment that "pays off for companies according to the companies interviewed. The return on Prevention (ROP) is assessed at 2.2." Summary, Page 34).	*Calculating the International Return on Prevention for Companies: Costs and Benefits of Investments in Occupational Safety and Health*, Report 1/2013e, published by German Social Accident Insurance, (Deutsche Gesetzliche Unfallversicherung) [DGUV], Berlin, , February 2013.
300% "for every $1 invested in safety you will expect $3 to $6 in return"	General Safety	Per Liberty Mutual Research Institute…Cited in "The ROI of Safety," *Business Week* special advertising section, appearing in the September 12, 20005 issue of *Business Week*. www.businessweek.com/adsections/2005/pdf/0534_roi.pdf
51 to 55% reduction		The Benefits of Participating in VPP, U.S. Occupational Safety and Health Administration (OSHA), 2001.
25%	American Textile Manufacturers Institute (ATMI) instituted the "Quest for the Best in Safety and Health" program in 1993).	The Benefits of Participating in VPP, U.S. Occupational Safety and Health Administration (OSHA), 2001.

Notes

Minimum without reduction % = 25%.
Maximum = 600%.
Average without reduction % = 224.6

Suggestion

Use 225%.

6

A8. Benefits of Safety for Productivity

20%	Reduction of injury and illness rates.	Huang, Yueng-Hsiang, et. al, "Financial Decision Makers' Views on Safety," *Professional Safety*, (ASSE), April 2009.
6%	Productivity Improvement from 50% reduction in accident rate.	Van Den Raad, W.P., *Safety & The Bottom Line: Proving The Financial Benefits of Your Safety Initiatives*, presented at: Proactive Accident and Incident Reporting & Investigation Conference. IIR Ltd, Stakis St Ermins Hotel, London, 7-8 Dec 1999. W.P Van Den Raad BSMS Inc. Franklin, IN, 46131, USA.
32%	Reduced recordable injuries (Mobil Chemical)	"The Benefits of Participating in VPP," U.S. Occupational Safety and Health Administration (OSHA), as cited in *White Paper Addressing The Return On Investment for Safety, Health, And Environmental (SH&E) Management Programs*, Business of Safety Committee (BOSC) Paper #6 American Society of Safety Engineers (ASSE), June 8, 2002. Available at http://www.asse.org/bosc-article-6/
13%	Improvement in productivity (Ford)	
16%	Reduction in Scrap (Ford)	
35%	Increased production (Kerr McGee)	
"43% of executives believe greatest benefit of safety is increase in productivity."	2012 paper published by OSHA cites a survey of 231 companies with more than 100 employees. It found 43 percent of financial decision-makers believed the biggest benefit of their company's workplace safety program was an increase in productivity.	Cited in Smith, Danny, "The Other Side of the Coin," *Occupational Health and Safety*, April 2015. Available at https://ohsonline.com/Articles/2015/04/01/The-Other-Side-of-the-Coin.aspx
to 7% productivity improvement	Best in class manufacturers report: "5 to 7 percent OEE (Productivity Improvement) 2 to 4 percent reduction in downtime And 50% reduction in accident rate" Better than average performers …	Ludwig, Steve, *Safety Maturity: Three Crucial Elements of Best-in-Class Safety*, Rockwell Automation, 2014 (available at www.rockwellautomation.com/go/smiwp) page 3.
94 % reduction in accident rate	Best in class companies (top 20 percent on performance score) have far fewer workplace accidents—only 1 in 2,000 employees, versus 1 in 111 employees. 1 accident in 111 workers is an incident rate of 0.9 percent, 1 in 2,000 is 0.05%. Going from almost one percent to ~1/20 of one percent, is a reduction of 94.4% relative to the original.	
-44%	'Run till broke' strategy	Data from "US coal industry challenged by over a decade of declining productivity," SNL Financial, 6 March 2014, as cited in Productivity In Mining A Case For Broad Transformation, Ernst & Young Global Mining & Metals, Ltd; 2014. (Page 3)

Notes

Minimum = 2%. Average (without [-44%]) = 13.7%

Suggestion

Use 14%. Maximum = 35%

A9. Benefits from Control of Fugitive Materials

67% reduction in spillage (and in resulting cleanup costs)	Reduction in Spillage (from 8000 tons/month to 5000 tons per month, at $5/ton cleanup costs.)	Martin CST Contract (per Lou G's presentation).
30% (from 18 to 23.5 months service life)	Increased Idler Life due to reduction in fugitive material.	Martin CST Contract (per Lou G's presentation).
404%	ROI on Chute Modification to Control Spillage.	Martin CST Contract.
50 percent increase in idler life for clean conditions.	Up to 50% reduction in idler life for dirty or wet environment.	*Bulk Material Belt Conveyor Troughing and Return Idlers: Selection and Dimensions*. Standard 502-2004, Conveyor Equipment Manufacturers Association (CEMA), 2004. (Figure 2-5).
Carryback causes between 5 and 25% of total belt wear.	"This clinging material causes deterioration which may vary from 5 to 25% of the total wear of the belt."	Ridgeway, John J. A, "An Automatic Belt Cleaner," *Engineering and Mining Journal*, Volume 92, August 26, 1911, page 391.

A10. Benefits from Extending Life of Various Conveyor Components

45% ($5,680)	Increase in Pulley Life from Life Cycle Costing	Oxley, T., and M. Myers, "Economics Of Conveyor Systems Component Selection: The Total Cost Of Ownership Approach," *Mining Engineering*, Vol 57, No. 3; March 2005, p 43.
8% ($255,800)	Energy Savings from Motor Selection using Life Cycle Costing	
400%	TC Blade Life Increase using Water	Martin Engineering Key Account Report (Proprietary) El Abra Copper Mine, 2005 (8,000 TPH copper ore, 60 inch belt, 7 m/s)
+3%	Additional maintenance costs first 2 years for buying on price rather than life cycle costs.	Moore, Ron, "The business case for life cycle cost," *Reliable Plant*, (4-3-2008), available at http://www.reliableplant.com/Read/11309/life-cycle-cost
3,123% ($102,703)	Automated Lubrication Improved Main Bearing life and Downtime reduction savings per year.	Bommer, Kathleen, and Mark Hawkins, "Automatic Lubrication in Mining Applications Improves Reliability and Decreases Maintenance Costs," *Proceedings of the 2015 SME Annual Conference & Expo, Denver*, CO, February, 2015, p.622.
150%	ROI from installing SHD after 1 year	MIBRAG beltcleanercostanalysis.xls, August, 2002, Martin Engineering proprietary research.
258%	ROI from installing SHD after 3 years	

Suggestion

Use 30%

A11. Probability of Accidents

Probability of Accidents			
Work–Related Fatalities (2001)	**Industrial Fatal Accidents per 100,000 Population**	**Industrial Lost-Time Accidents (3+ Days) per 100,000 Population**	**Industrial Fatal Diseases per 100,000 Population**
Minimum	3.8	2,887	43.0
Median	12.7	9,725	63.0
Maximum	19.1	14,542	89.3
Takala, Dr. J., *Introductory Report: Decent Work – Safe Work*, XVIIth World Congress on Safety and Health at Work, International Labour Organization, Geneva). Also as presented at the 27th World Congress on Safety and Health at Work, Orlando, 2005. (Extracted from Table 2)			
Accident Rates per 1000 workers		**Fatal Accidents**	**Lost-Time Accidents**
Annual Rates for 12 year period (1998 to 1999)			
Injury and Fatality Rates/Conveyors South Africa		0.23 per 1,000 workers	0.43 per 1,000 workers
Injury & Fatality Rates/Mining Industry South Africa		0.9 per 1,000 workers	13.6 per 1,000 workers
Totaled from Table 2 (page 16). As cited in Dreyer, E., and P.J. Nel, *Final Project Report: Best Practice Conveyor Belt Systems*, Safety In Mines Research Advisory Committee (SIMRAC), Anglo Technical Division Project Number GEN 701, South Africa, July 2001, available at http://docslide.us/documents/best-practice-conveyor-belt-systems.html			
Conveyor Systems Comparison of conveyor fatality rates for the SA and USA mining industries (Source: DME database & COM website) US Mining Industry Accident Data, as cited in Dreyer, E., and P.J. Nel, Final Project Report: Best Practice Conveyor Belt Systems, Safety In Mines Research Advisory Committee (SIMRAC), Anglo Technical Division Project Number GEN 701, South Africa, July 2001, available at http://docslide.us/documents/best-practice-conveyor-belt-systems.html		1998/1999 South Africa Conveyor Fatality Rate ~ 0.03 per 1,000 workers	1998/1999 USA Conveyor Fatality Rate ~0.010 per 1,000 workers

Suggestion

Fatal—Minimum = 3.8/100,000; Average = 34/100,000;
Maximum = 95/100,000.
Lost-Time—Minimum = 43; Average = 3756.
Use 3750.

A12. Cost of Downtime

$60,000 AUD	Head Pulley Failure	Roberts, Alan W., "Conveyor System Maintenance and Reliability," *ACARP Project C3018 Final Report*, Australian Coal Industry's Research Program (ACARP), November 1996. acarp.com.au
$18,750 AUD	Splice Failure	
$7,000 per hour	Machine Downtime	Campbell, Bill, "Taking Safety to the Bank," *Rock Products*, Volume 118, issue 6, Mining Media International, Denver, Colorado, June, 2015, Page 26-27
$30,000 SK/hour	Spillage stops Conveyor	Oberg, Ola, Material Spillage at Belt Conveyors, Royal Institute of Technology, Stockholm, 1987.
$40,000 SK/hour	Spillage stops Conveyor	
$30,000 USD	ROI from installing SHD after 1 year	Proprietary Martin Salesman Questionnaire, Martin Engineering, August, 2015
$50,000 USD	Plugged Chutes	Martin Salesman Questionnaire August, 2015, Brad Neptune

Suggestion

Use $40,000/Hr.

A13. Savings in Insurance due to Safety Programs

From $13.78/per $100 in wages to $1.28/$100 in wages	Coal Mining Safety Program	All three as cited in *The Return On Investment (ROI) For Safety, Health, And Environmental (SH&E) Management Programs* (Business of Safety Committee (BOSC) Paper #6. Council on Practices and Standards (CoPS) of the American Society of Safety Engineers (ASSE). June 8, 2002, available at http://www.asse.org/bosc-article-6/
$4.25/hour to $0.18/hour	Fall Protection	
$70,000/year to $7,000/year	OSHA Consulation program	
28.5 incident rate ($50,000/year) to 8.3 incident rate ($4,000/yr)	Reduce Back and Shoulder Injury Reduction Program for reduced direct and indirect costs	
From 1.7 mod rate, to 0.999 mod rate; $61,000 in direct and indirect costs	Reduce Workman Comp Costs Savings	
From 17.9 to 0.6	Reduced Workman comp rate 85%	
75% for Excellent Record; 300% for a Poor Record	Changes in Insurance Premiums, due to company's safety record.	Malesic, Christian, "The Savings in Safety" *Insights* [Magazine of Independent Electrical Contractors (IEC)]. May/June 2011, ieci.org.
Companies with a history of zero or only minor incidents can see their insurance premiums drop to 75 percent of what their competitors are paying for the same policy, whereas poor incident history can lead to paying insurance premiums as high as 300 percent of the going rate.		
From 2.7 to 0.1	Reduce Case Workman Comp Rates	Thrall Car
70%	Reduce Workman Comp Costs	Monsanto
From 6.84 to 1.84 (73% savings)	Reduce Case Workman Comp Rates	Occidental
47 to 97%	Reduced Insurance Costs	State of Oklahoma - Safety Pays Program
20%	Reduced Insurance Costs	Alberta Canada Workman's Comp Board
Various case histories, from The Benefits of Participating in VPP, U.S. Occupational Safety and Health Administration (OSHA), 2001.		
All five above as cited in *White Paper Addressing The Return On Investment for Safety, Health, And Environmental (SH&E) Management Programs* (Business of Safety Committee (BOSC) Paper #6, Council on Practices and Standards (CoPS) of the American Society of Safety Engineers (ASSE). June 8, 2002. Available at http://www.asse.org/bosc-article-6/http://www.asse.org/professionalaffairs/action/return-on-investment-for-safety/		
4.9 to 9.0%	Average reduction in injury and illness rate	"Of the participants reporting a reduction in their I/I rate, the average annual reduction was 4.9% to 9.0%. Based on participant reports of injury cost management, only a few participants provided complete data from which to calculate the value of the impact of improved ergonomics on injury reduction. This was calculated to fall between $2,977 and $4,854 per year (based on the incidence of MSDs and workers' compensation costs of each site)." *White Paper: Cost and Return on Investment of Ergonomics Programs*, Humantech, Inc., 2014, page 7.
Between $2,977 and $4,854 per year	Value of improved ergonomics on injury reduction	

Suggestion

Use Actual Cost x % Reduction in Incident Rate

A14. Improvements in Financial Results (as Increase in Share Price) from Improved Safety

Improvement in Share Price Value from Environmental Programs	0.2 to 0.5%	*White Paper: The Return On Investment (ROI) For Safety, Health, And Environmental (SH&E) Management Programs* (Business of Safety Committee (BOSC) Paper #6, Council on Practices and Standards (CoPS) of the American Society of Safety Engineers (ASSE), June 8, 2002, available at http://www.asse.org/bosc-article-6/
Investments in Environmental Management	6.0 to 16.2%	
Companies with Good Environmental Records Compared to Average Electric Utilities	7%	
Alcoa states that when it began focusing on becoming a safer company, the Pittsburgh-based aluminum manufacturer saw its earnings increase from $0.20 a share to $1.41 in only five years, and sales grew 15 percent each year during the same period. Along with increased profits, the company reported that its lost time due to employee injuries declined over the course of 10 years.		Morrison, Kyle W., "The ROI of safety" *Health+Safety Magazine*, Vol. 189 No. 6, National Safety Council, Itasca, IL, June, 2014
In 2002, France-based Schneider Electric believed it already had a good safety program. The company's OSHA recordable injury rate was 3.6 per 100 full-time workers – below the industry average at the time. "… As a result of investing in safety, the company saw its injury rate drop to 0.5 in 2013. That equals about 900 fewer people injured …" On top of that, Schneider Electric is seeing more than $15 million annual savings in direct costs alone – which, as previously noted, pales in comparison with indirect costs that could be 2 to 3 times more than direct cost.		
Benefit of performance-enhancing culture: • Stock price growth at 12 times the rate … • Revenue growth at 4 times rate … of companies without the performance-enhancing culture, for the 12-year (1977-1988) study	"Companies with performance-enhancing cultures significantly outperform companies without such cultures."	Ryan, Dennis, "Safety Perception Survey Yes, You Can Conduct Your Own" *Professional Safety*, American Society of Safety Engineers, December 2009. www.asse.org, citing Kotter, J.P., and J.L. Heskett, Corporate Culture and Performance, Free Press, New York, 1992.
In *Corporate Culture and Performance*, John P. Kotter and James L. Heskett found that a performance-enhancing culture contributes to significant growth in revenue, employment, stock price, and net income.	"For greater perspective, Kotter and Heskett state: 'To consider that the difference between a nine-hundred percent and a seventy-five percent appreciation in equity value is somewhat attributable to the strength of a company's corporate culture highlights the significance of this often-overlooked issue.'"	Cited in Charfen, Alex, "Creating a Culture of Performance" *Shale Oil & Gas Business Magazine*, January 27, 2016, available at http://shale-mag.com/2016/01/27/culture-of-performance

Suggestion

Use 7%

A15. 'Benefits of Design for Safety' or 'Prevention through Design'

37%	Percentage of workplace fatalities which definitely or probably had design-related issues involved.	Guidance On The Principles Of Safe Design. The Australian Safety and Compensation Council, 2006, Page 6; citing *The role of design issues in work-related injuries in Australia 1997-2002* NOHSC (National Commission), 2002. Occupational Health & Safety.
30%	Percentage of work-related serious non-fatal injuries where design contributed	
4.9% to 9.0%. Annual reduction in illness/ injury rate (average).	Of the participants reporting a reduction in their [illness/ injury] rate, the average annual reduction was 4.9% to 9.0%.	White Paper: Cost and Return on Investment of Ergonomics Programs, Humantech, Inc., Ann Arbor, MI, 2014. Pages 7 and 10.
378%. Average Return on Investment in ergonomics program.	"Of the survey participants, four (4) provided complete data, which enabled us to complete the ROI calculation for each site. Based on these four sets of data, the ROI of the site ergonomics programs ranged from 77% to 1,513% per year. The average for the group was 378% annual ROI."	

Suggestion

Use 30%

"To me one of the main uses of this book will be to help answer this question: 'How do I convince the boss that safety pays?' Budgets are managed so tightly that no manager wants to risk spending now to save later. So when a project is presented based on reducing direct costs, it has become a tough sell."

R. Todd Swinderman, P.E., Author

Chapter 35 Connecting the Dots

Making the Link Between Safety and Profitability

INTRODUCTION

Despite the writing of thousands of articles and books, despite the regulatory efforts of governments around the world, despite the promotional efforts of associations and practitioners who have preached safety for decades, industry still has not made the connection between cleanliness, safety, and productivity.

All have been unable to cement the relationship of safety to acclaimed but unadopted practices of buying on value, reducing risk, and embracing a safety culture. They have been unable to 'connect the dots' between investments in safety and long-term benefits—the return on safety.

As a result, questions remain for those who want to improve a company's safety performance and its financial performance. These questions include:

- *From the Employee*: How can I convince the boss that safety pays?

- *From a Supplier*: How can I convince customers to buy on value rather than price?
- *From an Engineering Firm*: How can we convince the customer that a safer design justifies a higher level of investment?
- *From a Senior Executive*: How do investments in safety increase shareholder value?

But, when a culture of safety is deeply and effectively embedded in a company's philosophy, management style, purchasing procedures, and work practices, these questions are routinely answered, enriching employees' lives, protecting the environment, and improving the bottom line.

A Review of Financial Techniques

Chapter 34 The Payback for Safety discusses the techniques that can be used to evaluate safety investments. They include:

Return on Investment Method (ROI)

The ROI approach (**Figure 35.1**) is most useful for calculating the savings in direct costs that can be realized with minimal investment and within a relatively short time frame. Usually, there is minimal investigation into the direct costs. The result is that the total cost is the sum of the initial price and the reductions in budget line items. These projects are often small enough in cost that they fall within the local plant management's approval authority. An investment with a ROI of one year or less is usually considered an easy decision—particularly, if it improves an operation's safety, cleanliness, or productivity.

The ROI method can also be useful as a quick look to judge whether a larger or longer-term project may be viable. It serves as a first step in determining whether further data collection and financial analysis may be justified.

Net Present Value Method (NPV)

The NPV method (**Figure 35.2**) is useful for comparing somewhat larger and more complex investments with different options and time frames. The NPV method requires knowledge or estimates of the cost of money (discount rate [R]), the initial investment, and the costs and savings in annual cash flows over time, where i = number of years. The NPV approach is to list, by year, the cash flows—as savings minus costs—and discounts, and bring the totals forward into today's money. The NPV method is useful when all significant costs and savings—both direct and indirect—are tallied.

A common application of the NPV method is known as Life Cycle Costing. This is where an investment in a less expensive but less reliable component is compared to that required by a more expensive but more reliable option. The option with the larger NPV would be the preferred investment.

The NPV approach lends itself nicely to the testing of assumptions. It is relatively easy to change one variable—plus or minus a given percentage—to see how sensitive the projected NPV is to sourcing issues or price increases.

The discount rate that would make the NPV equal to zero is called the Internal Rate of Return (IRR). (**Figure 35.3.**) The IRR is

$$\text{ROI} = \frac{\text{Total Savings}}{\text{Total Costs}}$$

$$\text{ROI x 100} = \text{ROI\%} \qquad \frac{1}{\text{ROI}} = \text{Years to Payback}$$

Figure 35.1.

Return on Investment Formula.

$$\text{Net Present Value} = -\text{Initial Investment} + \sum_{i=1}^{i} \frac{\text{Annual Cash Flows}}{(1+R)^i}$$

Figure 35.2.

Net Present Value Formula.

$$\text{Internal Rate of Return} = \text{What Rate R Will Make NPV} = 0?$$

$$0 = -\text{Initial Investment} + \frac{\text{Cash Flow Year 1}}{(1+\text{IRR})^i} + \frac{\text{Cash Flow Year 2}}{(1+\text{IRR})^i} + \frac{\text{Cash Flow Year 3}}{(1+\text{IRR})^i} \ldots$$

Figure 35.3.

Internal Rate of Return Formula.

useful when comparing different options for the same investment. If the IRR is a positive percentage, the project is probably viable. When more than one option is considered, the investment with the larger IRR percentage is probably the best financial option.

Normally, the result of an NPV calculation would be a positive number. For example, when considering the purchase of a machine to increase production, a company would not buy the machine if it did not produce positive cash flow over its life. The best machine to buy would have the best or highest positive NPV.

When considering options for mitigating risks, the NPV calculation often results in a negative number because risk cannot be totally eliminated. In the case of safety investments, the NPV result with the lowest negative number would most likely be the best investment. To put it another way, the NPV calculation may still use negative cash flows, but it is the minimum cost for the maximum risk reduction that should be pursued.

Figure 35.4.

Inflation-Adjusted Value of a Statistical Life Formula.

$$VSL_{2013+n} = VSL_{2013} \times (1+PPI/100)^n$$

n = The number of years since 2013

Where PPI is the Producer Price Index and the VSL is country-specific

Figure 35.5.

Investments in conveyor improvements can be considered for these goals.

Goals for Improvement Investments
Control Fugitive Materials
Control Dust
Minimize Spillage
Decrease Carryback
Increase Safety
Reduce Personal Injuries
Reduce Industrial Diseases
Reduce Noise
Upgrade Guarding
Increase Productivity
Reduce Maintenance Time
Increase System Availability
Increase Throughput
Increase Equipment Reliability
Other
Reduce Enterprise-Wide Risk
Justify Design for Safety Engineering
Improve Community Relations
Increase Shareholder Value

Value of Statistical Life Method (VSL)

The VSL method can be used in two ways. The first uses an estimate of what the operation would be willing to spend to reduce risks and injuries over the lifetime of the worker or the life of the plant. The second approach assumes the cost of an incident, and then calculates how much you could afford to spend to reduce that risk of incurring that incident by a stated amount. Knowing or estimating the cost of money (R), an NPV calculation can be made on the cost savings from avoiding incidents. In most countries, the cost of various degrees of injury is known or can be estimated; each operation will have its own specific data. The literature survey in **Chapter 34 Appendix** provides the average probability for the various incident categories. This information is used to estimate the savings in reducing incidents by quantity or level of severity.

Governments frequently use this method to evaluate whether the cost of implementing a regulation will reduce incidents and save society money. This technique is used to justify savings from safety when the savings fall into a less tangible category. The published or derived values of the Value of Statistical Life can be adjusted for inflation using **Figure 35.4**.

Combining the Methods

In the following, these techniques will be used with classic accounting procedures to show how these methods can be applied to a wide range of investment opportunities. **Figure 35.5** lists some of the types of safety investment scenarios that can be investigated and justified using the techniques outlined in **Chapter 34 Payback for Safety**. There are many more applications where less tangible data can be collected and used to justify improvements in safety, cleanliness, and productivity.

Questions to be Answered

While posed as different questions from different personnel, a common theme is expressed almost universally: How do I convince a superior there is a return on investment for those product features and worker activities that directly or indirectly improve safety?

From the Employee: How can I convince the boss that safety pays?

- Collect Data

Collecting the required data is important. If the position advocated is data-free, the status quo (or the boss) always prevails. The case may not need a lot of

ROI for Controlling Fugitive Materials

Happy Company handles 5 million tons per year of hap, the raw material for producing happiness. At $50 per ton, this raw material has an annual value of $250,000,000. The Happy Company operation has 50 conveyors using 30,000 feet of belt. Spillage, dust, and carryback were measured at 2.8 percent of annual throughput. Half of the cleanup is done manually at the rate of one ton per hour. An outside contractor, Serenity Un-Ltd., has proposed to reduce the spillage to less than 1 percent by installing belt cleaners and maintaining the transfer points for an annual cost of $1,250,000. Happy Company wants to know the ROI on cleanup labor reduction based on the proposal.

	Happy Company Cleaning	Serenity Un-Ltd. Proposal
Spillage & Carryback	140,000 t	50,000 t
Labor Required @ 2,000 h/y per worker	140,000 t x 1 t/h x 50% = 70,000 h	50,000 t x 1 t/h x 50% = 25,000 h
Cost of Labor @ $40/h	$2,800,000/y	$1,000,000/y

$$\text{ROI} = \frac{\text{Savings}}{\text{Cost}} = \frac{\text{Current Cleaning Cost - Future Cleaning Cost}}{\text{Contract Price}}$$

$$\text{ROI} = \frac{\$2{,}800{,}000/\text{y} - \$1{,}000{,}000/\text{y}}{\$1{,}250{,}000/\text{y}} = \frac{\$1{,}800{,}000/\text{y}}{\$1{,}250{,}000/\text{y}} = 1.44 \text{ or } 144\% \quad \mathbf{(.69 \times 12 = 8.3\ months)}$$

ROI for Hiring Serenity Un-Ltd.

In summary, the return on investment for the contract to reduce Happy Company spillage is 144 percent, indicating a payback in 8.3 months.

When presented with such numbers, a common reaction from management is that the company has the people on staff to do the cleaning and maintenance so it is a supervision problem rather than a fugitive material problem. In reality, an examination of outage priorities and maintenance work accomplished almost always shows that maintenance of fugitive material control components—belt cleaners and spillage prevention systems—consistently receives a low priority. As a consequence, these maintenance tasks are rarely completed, and the performance of the systems for fugitive material control falls.

The investment and timing would be more complicated and could be analyzed in greater detail over a multi-year period. For example, the first year would most likely be spent installing and upgrading fugitive material control components so the reduction from 2.8 percent spillage to 1 percent would take more than a year. This would indicate a multi-year contract may be required to realize the total savings.

In addition, it is known from experience that a significant number of accidents are related to the cleaning of fugitive material around conveyors, and that reducing spillage increases the life of components by 25 to 40 percent. As a result, there are additional savings that could be put into a Net Present Value analysis. The key to this analysis is that the current amount of spillage is measured, and the current cost of manual cleaning is known.

Note:
Chapter 31 of Martin Engineering's book *FOUNDATIONS™ The Practical Resource for Cleaner, Safer, More Productive Dust and Material Control, Fourth Edition*, provides a qualitative method for assessing performance in reducing fugitive material.

Price vs. Cost

Happy Company conveyors use approximately 3,750 troughing and 1,500 return idlers. Idlers would last an average of four years. In an attempt to reduce spare part costs, the Happy Company Central Purchasing Department sourced replacement idlers from the lowest cost vendor. In summary, the purchasing 'savings' from buyin on price rather than life cycle cost was negative 90 percent.

Happy Company Central Purchasing Savings

	Idlers Purchase Based on Life Cycle Cost	Idlers Purchased Based on Low Initial Price
Average Number of Return Rollers Replaced/year	1,500/4 =375	1,500/4 =375
Average Price of Rollers	\$105 X 375 =\$39,375	\$90 X 375 =\$33,750
Purchasing Savings		\$5,625

Cost of Maintenance Labor Due to Purchasing on Price

	Idlers Purchase Based on Life Cycle Cost	Idlers Purchased Based on Low Initial Price
Time to Replace Rollers	1h 100% of the time	2h 33% of the time
Labor Cost/y @ \$50/h	375 rollers x \$50/h x 1h/roller = \$18,750	375 rollers x 2/3 = 250 @ 1h/roller x \$50/h =\$12,500/y 375 rollers x 1/3 = 125 @ 2h/roller x \$50/h =\$12,500/y Total = \$25,000/y
Additional Labor Cost		\$25,000 -\$18,750 = \$6,250/y

However, despite specification to an industry standard, the lower-cost replacement idlers varied slightly in length and end shaft design. The Happy Company maintenance department had no idea if the next order of rolls would be from the same low-cost provider. About one third of the time the low-cost replacement rollers would not fit the installed return-roll drop brackets, so the change-out procedure would also involve replacing or modifying the idler drop brackets. This increased the replacement time by one hour per idler.

$$\text{ROI} = \frac{\text{Savings}}{\text{Cost}} = \frac{\$5{,}625}{\$18{,}750 - \$25{,}000} = -0.9$$

Negative ROI from Buying on Price

There was a larger 'savings' of \$28,000 on the purchase price of the approximately 900 troughing idlers replaced every year. The reduced price was based on the total volume of idlers purchased. Consequently, the Purchasing Department was reluctant to listen to the original supplier and returned to buying return rollers based on cost.

Rather than living with the problem, the original supplier could, with the Maintenance Department's help, present a more in-depth analysis to counter Purchasing's decision to buy the lower-price idlers. For example, if just one hour of unplanned downtime (at \$41,167 per hour, as shown in the following equation) is created by the need to adjust the mounting to install the lower-priced idlers, the savings from the lower-cost idlers disappear.

$$\text{Cost of Unscheduled Downtime} = \frac{\text{Annual Sales (Production Goal)}}{\text{Annual Operating Hours}}$$

$$\$41{,}167 = \frac{\$250{,}000{,}000}{6{,}000}$$

Cost of Downtime

Similarly, the cost of one lost-time accident—with an average of \$38,000 per incident—arising from the additional worker exposure to the hazard due to the extra installation time and bracket rework required, would also overwhelm the savings from the purchase of the lower-cost equipment.

Presenting this risk along with actual knowledge of the operation's unplanned downtime and incident rate could be used to convince the Purchasing Department the benefit of lower price was not worth the risk.

data, but sufficient data will be important for the authority to make a decision. Anything can be measured using the techniques discussed in **Chapter 34 The Payback for Safety**.

In many cases, the data needed is already being collected somewhere in the company or available on the internet. Seek out information from others—chances are, somebody has had the same issue and can provide useful information that will save research time.

- Develop a Plan of Action for Change

  A plan should be based on facts, not opinion. From the data collected, a suitable course of action should be evident. If it is not present, maybe the right information was not collected or perhaps the problem identified is not really a problem—or is not THE problem—after all. The plan should contain a statement of the problem, the proposed solution, and the expected results.

- Calculate the Return on Investment (ROI)

  At the department level, a proposal will have to show that spending money from this year's budget will have a quick payback. Typically, that is because one of the main things plant management and department heads are held accountable for is staying within the monthly or annual budget. If this is the case, a simple ROI calculation (**Figure 35.1.**) will usually suffice.

  If the project involves spending more money than the boss can authorize, it is likely the calculation will be more involved, and the operation may require that the project be submitted for the next year's capital budget. With larger expenditures, the payback is typically extended over a period of years, so the project will need to use the Net Present Value analysis approach.

- Present the Case

  Complaining to the boss and making unsubstantiated claims is not going to get your boss to take action. The boss has probably heard the complaint a thousand times, is busy handling 'real' problems, and wants solutions, not complaints. A more successful tactic is to state the problem, provide facts and offer proposed solution(s).

  A professional presentation with elaborate graphs and a designer cover is not needed, but putting the proposal on paper is important. State the problem and use photos if possible. Offer a solution, including a discussion of how it will improve the situation, and present the savings divided by the cost (the ROI). Include any backup information or references you have used.

  Once the proposal is on paper, the request is harder to ignore and easier for the boss to convince superiors that the project makes sense and is cost-effective.

The most important tool is an intimate knowledge of the process and an understanding where changes will make a difference in production. If the boss does not understand or appreciate the relationship between cleanliness, safety, and production, an important step in the presentation is to provide the proof to convince the boss of this relationship. The more similar the proof is to the plant's situation the better.

This proof can be drawn from a number of sources. These include use of one or more of the sections or references in the *FOUNDATIONS*™ books, trade publication success stories, or results from similar investments in other parts of the plant or similar operations.

- Near miss incidents provide an opportunity to avoid actual accidents.
- Dust, spillage, and carryback are responsible for 85 percent of premature equipment failures and cleaning up fugitive material is a source of over a third of all serious accidents.

The Value of Reduced Risk

Happy Company is considering a major expansion to add $100,000,000 in production capacity (and hence sales) of its finished product, Happiness. The investment involves conveyors and process equipment. Two bids were received. The low bid was $100,000,000 and the value-added bid was $110,000,000, which included about $1,000,000 in extra design costs and $9,000,000 in higher-quality components to increase reliability and reduce maintenance costs. Justin B. Fine, the CEO of Happy Company, wants to know if the extra $10,000,000 is worth the investment.

Based on research, the low bidder's system typically takes 18 months to get up to full production after start-up, with additional, unbudgeted costs of 3 percent of the project. On the other hand, project history for the value-added proposal is a six-month ramp-up to full production with no unbudgeted additional costs. In addition, the value-added bidder can prove from past jobs an improvement in reliability which reduces maintenance cost one half of one percent of the total investment cost.

As shown in the tables below, by using the assumptions, Option B – Value-Added Bid produces a better 5-year Net Present Value ($NPV_{n=5}$) and Internal Rate of Return ($IRR_{n=5}$). The risk reduction included in the analysis is based on a smooth start-up and reduced continuing maintenance costs.

Assumptions for Happy Company Investment

Assumptions	Option A - Low Bid	Option B - Value Bid
Discount Rate	5%	5%
Gross Profit Margin	30%	30%
Additional Start-Up Costs	3% of Investment/18 months	0%
Maintenance Cost	2% of Investment 5% of Belt Cost	1.5% of Investment 4.5% of Belt Cost
Belt Cost	$20,000,000	$22,000,000

Option A - Low Bid NPV over 5 years

Option A - Low Bid 100,000,000	Year 1 (000)	Year 2 (000)	Year 3 (000)	Year 4 (000)	Year 5 (000)
Sales	48,000	92,000	1,000,000	1,000,000	1,000,000
Gross Profit	14,400	27,600	30,000	30,000	30,000
Maintenance	3,000	3,000	3,000	3,000	3,000
Un-Budgeted Start-Up Costs	1,500	1,500	0	0	0
Operating Income	9,900	23,100	27,000	27,000	27,000
$NPV_{n=5}$	-2,800				
$IRR_{n=5}$	4.0%				

Option B – Value Added Bid NPV over 5 years

Option B – Value-Added Bid 110,000,000	Year 1 (000)	Year 2 (000)	Year 3 (000)	Year 4 (000)	Year 5 (000)
Sales	67,000	100,000	100,000	100,000	100,000
Gross Profit	21,100	30,000	30,000	30,000	30,000
Maintenance	2,640	2,640	2,640	2,640	2,640
Un-Budgeted Start-Up Costs	0	0	0	0	0
Operating Income	17,460	27,360	27,360	27,360	27,360
$NPV_{n=5}$	-1,000				
$IRR_{n=5}$	4.7%				

Once the analysis is set up, the variables can be manipulated to see how sensitive the analysis is to unmet variables. In this example, if the maintenance percentages in Option A (Low Bid) and Option B (Value-Added Bid) are the same, the NPVs are almost equal due to the faster attainment of full sales in Option B.

There are several other benefits that could be added depending upon how the $10,000,000 extra investment is spent. For example: engineered chutes have been shown to increase belt life; investments in ergonomics have significant safety returns; or reducing maintenance time through design could significantly increase availability.

- Maintenance workers spend about 30 percent of their time gaining access to the equipment to be maintained which often results in rushing to complete repairs.
- One third of all safety incidents are related to maintenance activities.

From a Supplier: How can I convince customers to buy on value rather than price?

- Provide Desired Benefits

  The features of the product or service proposal have to be ones that provide a benefit for the customer. Extra features may mean extra cost, so you may need the ability to customize the goods and services to provide the features with the benefit(s) the customer values the most.

- Quality is a Given

  The product or service has to have an acceptable level of quality, or it probably will not perform to expectations. The product has to perform for the expected intervals between maintenance. Reliability is a function of quality and function. The quality and reliability of a product or service should be demonstrated through a third-party proof or test installation.

- Performance-Based Proposals

  Helping a customer meet availability goals is important. To do that, the supplier needs to understand the customer's expectations, convert them into measurable outcomes, and provide a proposal that improves both the performance and operational availability of the system. It is significant and useful to guarantee, in writing, that the proposed system will perform.

- It is Cost not Price

  It is common for shortsighted managers to focus on cost reduction by setting goals for purchase of a specified percentage reduction over the cost of the previous year's purchases. The price is simply the money that changes hands. If price is the measurement, it is likely the customer is stepping over large savings and costing the company significantly more than is saved.

  The true cost of an equipment purchase is the price plus maintenance, energy, and all the effort that goes into using the product or service. Quite often, a low price results in a low or negative ROI, especially if the purchasing decision causes reduced availability because the supplier has cut reliability to meet the artificially low price goals.

  The proposal should show, using Net Present Value analysis—often called Life Cycle Costing or Total Cost of Ownership—that the higher-priced product or service brings greater benefits over the long-term life of the system.

From an Engineering Firm: How can we convince the customer that a safer design justifies a higher level of investment?

- Reduced Risk

  Risk is a combination of frequency and severity. When a customer buys on price alone, it often means lower-quality materials and workmanship. Most likely, long-used standard design details are used to provide a product or system that is cosmetically an 'or equal' design at the lowest-possible price. This is buying yesterday's technology at today's prices.

  The risk of a customer going out of business because of an environmental disaster or fatal accident is real. Even if the customer does not go out of business, the damage to a brand may take decades to undo. A purchasing department that uses the lowest bid without considering the more expensive design increases risk. Unfortunately, this happens all the time.

  The risk to your bank is only financial but significant. An extra 10 to 20 percent spent on design typically adds one or two percent to the overall cost of the project but can significantly reduce risk. According to a 2007survey from KPMG, *Construction procurement for the 21st Century*, buying on price alone results in 35 percent of the projects being over budget, and 16 percent being delivered late, with a similar percentage ending up in court over disagreements on performance. Net Present Value analysis can be used to show how, over the life of a plant, the ROI for reducing risk through design over buying on price is significant.

- Increased Reliability and Availability

  The desire for higher throughput drives the march toward ever-faster and -wider conveyors that run longer periods of

Increasing Share Price for Happy Company

A profit and loss statement gives a summary of financial activity over a period of time while a balance sheet gives a snapshot of the financial condition of the company at a specific point in time, usually year-end. The profit and loss statements and balance sheets used in this chapter could be broken down into many more detailed line items but are meant to be illustrative and not detailed.

The fictitious Happy Company produces happiness, millions of tons of it per year. As can be imagined, there is an unlimited demand for happiness but the ingredients are scarce. Mining and producing happiness is an expensive, unpredictable, and messy process. Many employees at Happy Company have been injured or died trying to produce happiness over the years. New management wants to change the company culture and make happiness available to everyone.

Happy Company was introduced in *FOUNDATIONS™, 4th Edition*, to demonstrate the Return on Investment comparison for the purchase and installation of belt cleaners to elevate cleaning performance. The example included direct savings and some unspecified additional production savings for a one-year period. Safety investments often take years of continuous improvement to produce results. As a result, the financial analysis methods discussed in this chapter often require a multi-year view of Happy Company's financial performance.

This example presents a simplified first-year comparison for the change in Happy Company stock price, both with and without the Return on Investments from reducing fugitive materials. (**See ROI for Controlling Fugitive Materials**.) It is assumed that that $250,000 of the Serenity Un-Ltd. contract is for equipment so the reduction in the cleaning expense is $1,800,000 with an increase in depreciation expense of $50,000 per year for a net change in expenses of $1,750,000. The same ratios are used for cost of sales, gross profit, and taxes.

The department manager is going to look at this as a reduction in the maintenance staff of about 13 cleaning people in exchange for an investment of $1.25 million. The manager would find it hard to lose the people and would wonder if the Serenity Un-Ltd. contract can be justified. But the corporate manager will see this as a sales increase of $4.5 million for an investment of $1.25 million, resulting in a stock price increase of 5.2 percent.

Simplified Projected Profit and Loss Statement for Happy Company

Happy Company Profit & Loss Statement ($000)	Without Serenity Un-Ltd. Contract	With Serenity Un-Ltd. Contract
Revenue (Sales)	250,000	254,500
Cost of Sales	200,000	203,600
Gross Profit	50,000	50,900
Expenses	30,000	28,250
Taxes	12,000	13,590
Net Profit	8,000	9,060

Simplified Projected Balance Sheet for Happy Company

Happy Company Balance Sheet ($000)	Without Serenity Un-Ltd. Contract	With Serenity Un-Ltd. Contract
Assets	75,000	75,250
Liabilities	50,000	48,966
Stockholders' Equity	25,000	26,284
Liabilities & Stockholders' Equity	75,000	75,250

Happy Company Stock Price

10,000,000 Shares	Without Serenity Un-Ltd. Contract	With Serenity Un-Ltd. Contract	% Change
Stock Price	$2.50	$2.63	5.2%

time without maintenance. The development of systems and components to meet these higher performance requirements is not linear. Today's belts are capable of launching more material off the head pulley which creates greater impact forces than the receiving station components can reliably handle. The result is unplanned stoppages to repair belt damage, to clean spillage, or to replace impact idlers. Unless the components are designed to be service-friendly, availability is further impacted by the mean time to repair (MTTR). A Net Present Value (life cycle cost) analysis can be used to show that increasing efforts during initial design to increase reliability and reduce maintenance turnarounds will save considerable downtime. If these initial designs consider access and ergonomics, further savings from safety can be proven.

From a Senior Executive: How do investments in safety increase shareholder value?

- Reduced Operating Costs

  The Mine Safety and Health Administration (MSHA) has estimated that 85 percent of all conveyor problems result from fugitive materials. The increased component life provided by a clean system and the use of specialty maintenance services has shown over and over to provide significant direct savings. Cleanliness also provides indirect cost savings in terms of reduced injuries and exposure to risk. Performance-based specifications and systems designed to operate more cleanly require upfront thought and effort but can be shown through experience-based data to provide significant savings in operating costs. Operating cost savings go right to the bottom line which in turn will improve stockholder value and share price.

- Safety Pays

  Investments in a wide variety of activities and equipment are the means to the end result, increased safety. There are the tangible savings in insurance, training replacements, reduced inspections and fines, and so on.

  The really big returns on investments are often for the less-tangible savings, such as reducing risk, increasing morale, being the employer of choice, and reduced staffing.

  Since it is widely, but wrongly, assumed that these less-tangible costs cannot be measured, these costs are often over looked. Chances are that there are numerous reports and statistics generated that are never used for making decisions, let alone used to justify investments in safety. It can be hard to sort out the measurements that really matter, but finding useful data that can be acted upon is the key to improving safety.

  Any or all of the best practices and financial techniques discussed in this book, if applied in good faith through competent management, will increase shareholder value, especially when compared to those companies that practice production at all costs. The 'Run Until Broken' mindset really does mean 'Run Until Broke.'

CLOSING THOUGHTS

In this book, we have discussed at length the psychology of accidents. Safety incentives based on incident rates are a common but often counterproductive attempt at increasing safety. Safety slogans and programs, if not backed up by a robust safety culture, are often unsuccessful.

The authors have also looked at the conveyor as a source of hazards and discussed the regulations, standards, and best practices to control those risks and protect those who must work on or around these systems.

The authors have illustrated how the maze of inconsistent, conflicting, and often politically motived national regulations hampers global safety. The efforts to improve safety are not easy. It takes talent, time, and leadership. True safety is a state of mind and a state of equipment.

The authors have laid out the many arguments in favor of safety-based investments and offered our concepts of best practices. The authors have tried to lay bare the excuses of those that buy on price at the sacrifice of mankind and the environment in search of phantom profits.

By **Connecting the Dots for Safety**, companies and executives are preparing for the next generation of machines and mankind. Hardly a day goes by that companies do not spend time assessing how to train the next generation of workers, protect the environment, and improve their yields. It all comes down to a simple equation:

Cleaner + Safer = More Profitable.

Production Done Safely™ is proven to benefit the worker, the company, and the environment. ⚠

Letter from the Authors

Dear Reader,

We hope you have enjoyed this fascinating trip through the safety issues of your conveyor system. But more importantly, we hope you found it instructive and beneficial.

Belt conveyors are large pieces of industrial equipment. As we have discussed, conveyors offer ample opportunities for injury and even death. The first section of the book highlighted the danger zones of belt conveyors, followed with a chapter on the most common unsafe practices around conveyors. As we pointed out, the first step in being completely safe around belt conveyors is to realize where and how they can hurt you.

The next section of the book focused on mechanical systems and electrical devices that can be installed to address some of these danger areas. While many of these solutions do not prevent the root cause of the problem, they are a great leap toward the goal of **Production Done Safely™**.

The tips laid out in Section 3 are harder to implement. This portion of the book dealt almost exclusively with behaviors and a culture of safety. We offered some suggestions for improved work practices around conveyors.

The next step beyond acclimating to the dangers of a conveyor system is to honestly and systematically identify the hazards of a conveyor system. Section 4 offered several proven and logical methods to accomplish this.

While Sections 1-4 dealt with how to effectively respond to the hazards associated with conveyors, Section 5 took the approach of designing those hazards out of a conveyor system.

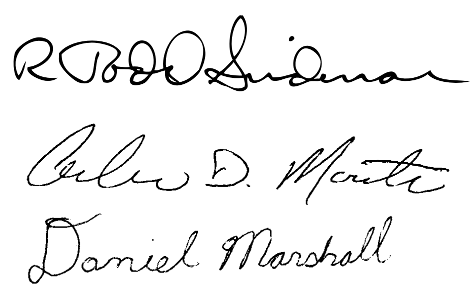
Any positive change to the culture and equipment should come with a financial benefit. Section 6 addressed the methods to quantify the intangible costs associated with safety. The ultimate goal was to develop and communicate a financial model that completely encompassed the risks of a conveyor, and quantified those risks. While an engineer or a plant manager will view the belt conveyor as a way to move the material, and also as a tool to complete the task, an accountant will see the same system as an asset of the company included in its production overhead costs. A robust method was developed to include the hidden costs of a safety failure—an accident—in the conveyor's initial justification. The ultimate goal was to realistically and accurately model the financial behavior of a belt conveyor to justify the cost of reducing risk.

To change a system, one must appeal to the functionality of the engineer's and plant manager's world, while at the same time appeal to the reality of the accountant's requirements. We believe this book has done both and will be a useful resource for anyone associated with belt conveyors handling bulk materials.

When all the thought processes of this book are combined, a facility can achieve its goal of **Production Done Safely™**.

Sincerely,

The Authors



APPENDICES

Bibliography

Universal References

Belt Conveyors for Bulk Materials. Naples, FL.: CEMA, 2014. Print

Swinderman, R. Todd. *FOUNDATIONS™: The Practical Resource for Cleaner, Safer, More Productive Dust & Material Control*. Neponset, IL: Martin Engineering, 2009. Print.

Foreword

Other Sources of Inspiration

Herbert W. Heinrich, *Industrial Accident Prevention: A Scientific Approach*, 1931

Chapter 1

Northup, Tom. *Five Hidden Mistakes CEOs Make. How To Unlock the Secrets That Drive Growth and Profitability*. Solutions, 2008. Print.

Chapter 2

Giraud, Laurent, Serge Massé, Julie Dubé, Luc Schreiber, and André Turcot. *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*. Mississauga, ON.: Industrial Accident Prevention Association (IAPA), 2003. Print.

Lighting at Work. Sudbury: HSE, 1997. Print.

United States. Michigan Occupational Safety and Health Administration. General Industry Safety & Health Division. *Pinch Points*. Lansing: MIOSHA, 2011. Print.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Illumination*. 23 Oct. 2015. Web. 2 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Occupational Noise Exposure*. 23 Oct. 2015. Web. 2 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Permit-required Confined Spaces*. 19 Nov. 2015. Web. 2 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Safeguarding Equipment and Protecting Employees from Amputations*. 17 Dec. 2015. Web. 2 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Walking / Working Surfaces*. 19 Nov. 2015. Web. 2 June 2016.

Chapter 3

Center for Dairy Farm Safety. *Hazard Identification and Risk Assessment*. University of Wisconsin, River Falls.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Metal / Nonmetal Mine Fatality*. Mine Safety and Health Administration, 2000. Web. 21 June 2016.

Chapter 4

Australia. Standards Australia Limited. Conveyors – *Safety Requirements*. 3rd ed. Sydney: Standards Australia International, 2000. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – Belt Conveyors for Bulk Materials Handling*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – General Requirements*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. 1-86. Print.

Brazil. Brazilian Ministry of Labor & Employment. *NR22 Safety and Occupational Health in Mining*. 1999. Print.

* Canada. Canadian Standards Association. M421-11 (R2016) Use of Electricity in Mines. Toronto: Canadian Standards Association, 2011. Print.

** Canada. Ontario. *R.R.O. 1990, Reg. 854: Mines and Mining Plants*. 10 Dec. 2015. Web. 2 June 2016.

*** European Union. European Commission. *Early Detection and Fighting of Fires in Belt Conveyor*. Luxembourg: Publications Office of the European Union, 2013. Print.

**** Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Handling Equipment and Systems – Safety and EMC Requirements for Fixed Belt Conveyors for Bulk Materials (includes Amendment A1:2010) English Translation of DIN EN 620:2011-07*. Berlin, 2011. Print.

Guideline, Safety Around Belt Conveyors. Conveyor Manufacturers Association of SA. 2016. Print.

India. Bureau of Indian Standards. *Selection and Design of Belt Conveyors Code of Practice*. New Delhi: Bureau of Indian Standards, 1986. Print.

† *Safety Standard for Conveyors and Related Equipment*. New York, NY: American Society of Mechanical Engineers, 2015. Print.

Other Sources of Inspiration

American National Standards Institute, *Safety Requirements for the Lock Out/Tag Out*, 1993

ASME, *Safety Standards for Conveyors and Related Equipment*, 2015

Brazilian Ministry of Labour and Employment, *NR12*, 2010

British Standards Institution, *Conveyor belts for use in underground installations – Electrical and flammability safety requirements*, 2015

British Standards Institution, *Protection against lightning – General principles*, 2011

Deutsches Institut Für Normung E.V., *Belt conveyors for loose bulk materials – Basis for calculation and dimensioning*, 2011

Deutsches Institut Für Normung E.V., *Conveyor belts – Drum friction testing*, 2012

Industry & Investment NSW, *Guideline for the prevention, early detection and suppression of fires in coal mines*, 2009

International Electrotechnical Commission, *Protection against lightning – Part 1: General Principles*, 2010

International Organization for Standardization, *Safety of machinery – Emergency stop – Principles for design*, 2006

Mine Safety and Health Administration, *Fire Protection (Underground Coal Mines)*, 2003

Mine Safety and Health Administration, *Mandatory Safety Standards (Underground Coal Mines)*, 2016

* With the permission of Canadian Standards Association, (operating as CSA Group), material is reproduced from CSA Group standards, *Z432-04 (R2014)* – Safeguarding of Machinery, M421-11 (R2016) – Use of electricity in mines and M422-14 – Fire-performance and antistatic requirements for conveyor belting, which are copyrighted by CSA Group, 178 Rexdale Blvd., Toronto, ON, M9W 1R3. This material is not the complete and official position of CSA Group on the referenced subjects, which is represented solely by the standards in their entirety. While use of the material has been authorized, CSA Group is not responsible for the manner in which the data is presented, nor for any interpretations thereof. For more information or to purchase standards from CSA Group, please visit http://shop.csa.ca/ or call 1-800-463-6727.

** This excerpt is an unofficial version of Government of Ontario legal materials.

*** This Early Detection and Fighting of Fires in Belt Conveyors project did not receive funding from the Research Fund for Coal and Steel of the European Union, nor is the European Commission responsible for any use of the information contained in this report.

**** Reproduced by permission of DIN Deutsches Institut für Normung e.V. The definitive version for the implementation of this standard is the edition bearing the most recent date of issue, obtainable from Beuth Verlag GmbH, Burggrafenstraße 6, 10787 Berlin, Germany.

† Reprinted from ASME B.20 1-2015, by permission of The American Society of Mechanical Engineers. All rights reserved.

Chapter 5

Australia. Standards Australia Limited. *Conveyors – Safety Requirements*. 3rd ed. Sydney: Standards Australia International, 2000. Print.

Brazil. Brazilian Ministry of Labor & Employment. *NR 22 Safety and Occupational Health in Mining*. 1999. Print.

British Columbia. Ministry of Energy, Mines and Petroleum Resources Mining and Minerals Division. *Health, Safety, and Reclamation Code for Mines in British Columbia*. Victoria: Resource Management Branch, Ministry of Energy, Mines and Petroleum Resources, 2008. Print.

Canada. Government of Alberta. *Best Practices on Conveyor Safety*. Alberta Employment and Immigration, 2009. Print.

* Canada. Government of Alberta. *Occupational Health and Safety Code*. Edmonton: Alberta Queen's Printer, 2009. Print.

** Canada. Ontario. *R.R.O. 1990, Reg. 851: Industrial Establishments*. 10 Dec. 2015. Web. 2 June 2016.

Canada. Quebec Government. *Regulation Respecting Occupational Health and Safety in Mines*. Éditeur Officiel Du Québec, 2015. Print.

"Conveyor Pre-Start Alarm." 2 March 2014. Engineering 360 Forum. IEEE GlobalSpec. 3 June 2016. http://cr4.globalspec.com/thread/88550/Conveyor-Pre-Start-Alarm

*** Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Handling Equipment and Systems – Safety and EMC Requirements for Fixed Belt Conveyors for Bulk Materials (includes Amendment A1:2010) English Translation of DIN EN 620:2011-07*. Berlin, 2011. Print.

Great Britain. *Safety of Machinery – Auditory Danger Signals – General Requirements, Design and Testing*. London: British Standards Institute, 1992. Print.

Great Britain. *Safety of Machinery – Indication, Marking and Actuation – Requirements for Visual, Auditory and Tactile Signals*. London: British Standards Institute, 1995. Print.

Great Britain. *Safety of Machinery – Visual Danger Signals – General Requirements, Design and Testing*. London: British Standards Institute, 1996. Print.

Guideline, Safety Around Belt Conveyors. Conveyor Manufacturers Association of SA. Oct. 2013. Print.

Pfannenberg. *The Complete Spectrum of Signaling Technology Main Catalogue*. 12 Aug. 2015. Print.

"Startup alarms on all conveyors? How do you do it?" 12 July 2005. PLCS Forum. 3 June 2016. http://www.plctalk.net/qanda/showthread.php?t=16077

United States. Center for Disease Control and Prevention. The National Institute for Occupational Safety and Health. *Gravel Pit Worker Dies While Cleaning Off a Stalled Conveyor Belt – Iowa*. Center for Disease Control and Prevention, 18 Nov. 2015. Web. 9 June 2016.

United States. Center for Disease Control and Prevention. The National Institute for Occupational Safety and Health. *Mill Operator Caught in a Conveyor Discharge Hopper and Died of Mechanical Compression Asphyxia*. Center for Disease Control and Prevention, 18 Nov. 2015. Web. 9 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Conveyor Startup Fatalities*. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Conveyor Start-Up Warnings*. 31 May 2016. Web. 2 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Conveyors*. Web. 2 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Reissue of P07-21 – Clarification of Requirements of Conveyor Start-Up Warnings for 30 CFR §§ 56.14201 and 57.14201*. By Neal Merrifield. 21 Mar. 2012. Web. 2 June 2016.

USSR. USSR State Standards Committee. *Occupational Safety Standards System Conveyors General Safety Requirements*. Douglas County: IHS, 1980. 1-8. Print.

Western Australia. Department of the Premier and Cabinet. *Mines Safety and Inspection Regulations 1995*. 8 Dec. 1995. Web. 2 June 2016.

Other Sources of Inspiration

Standards Australia, *Safety of machinery – Part 1904: Displays, controls, actuators and signals – Indication, marking and actuation – Requirements for visual, auditory and tactile signals*, 2006

Standards Australia, *Safety of machinery – Part 1202: General principles – Technical principles*, 2006

* Used with permission from the Government of Alberta, Alberta Labour. ©Alberta Queen's Printer, 2016.

** This excerpt is an unofficial version of Government of Ontario legal materials.

*** Reproduced by permission of DIN Deutsches Institut für Normung e.V. The definitive version for the implementation of this standard is the edition bearing the most recent date of issue, obtainable from Beuth Verlag GmbH, Burggrafenstraße 6, 10787 Berlin, Germany.

Chapter 6

Australia. Queensland Government. Department of Natural Resources and Mines. *Testing of Conveyor Pull Wire Activated Emergency Stops*. By Peter Minahan. 2003. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery - Conveyors - General Requirements*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. 1-86. Print.

* Canada. Canadian Standards Association. *M421-11 (R2016) Use of Electricity in Mines*. Toronto: Canadian Standards Association, 2011. Print.

* Canada. Canadian Standards Association. *Z432-04 (R2014) Safeguarding of Machinery.* Toronto: Canadian Standards Association, 2004. Print.

** Canada. Government of Alberta. *Best Practices on Conveyor Safety*. Alberta Employment and Immigration, 2009. Print.

Coveyor Equipment Manufacturers Association. *E-Stop Application Guide for Unit Handling Conveyors*. 16 Dec. 2008.

Drake, Bob. "Rock Newscope." *Rock Products* Aug. 1995: 9. Print.

*** Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Handling Equipment and Systems – Safety and EMC Requirements for Fixed Belt Conveyors for Bulk Materials (includes Amendment A1:2010) English Translation of DIN EN 620:2011-07*. Berlin, 2011. Print.

Giraud, Laurent, Serge Massé, Julie Dubé, Luc Schreiber, and André Turcot. *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*. Mississauga, ON.: Industrial Accident Prevention Association (IAPA), 2003. Print.

Guideline, Safety Around Belt Conveyors. Conveyor Manufacturers Association of SA. Oct. 2016. Print

India. Bureau of Indian Standards. *Code of Recommended Practice for Conveyor Safety, Part 2: General Safety Requirements*. New Delhi: Bureau of Indian Standards, 1986. Print.

India. Bureau of Indian Stanards. *Low-Voltage Switchgear and Controlgear*. New Delhi: Bureau of Indian Standards, 2008. Print

Japan. Japanese Industrial Standard. *Safety of Machinery – Emergency Stop – Principles for Design*. Tokyo: Japanese Industrial Standard, 2011. Print.

Pilianidis, Theophilos, Athanasios Kasabalis, Nikolaos Mantzouranis, and Alexandros Mavvidis. *Start Reaction Time and Performance at the Sprint Events in the Olympic Games*. Komotini: Democritus U of Thrace, 2012. Print.

**** *Safety Standard for Conveyors and Related Equipment*. New York, NY: American Society of Mechanical Engineers, 2015. Print.

South Africa. South African Department of Minerals and Energy. *Mine Health and Safety Act 29 of 1996*. By Penuell Mpapa Maduna. 1996. Print.

Switzerland. International Organization for Standardization. *ISO 13850 Safety of Machinery – Emergency Stop – Principles for Design*. Geneva: International Organization for Standardization, 2006. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Electric Equipment; Examination, Testing, and Maintenance*. Mine Safety and Health Administration, 8 June 2016. Web. 10 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Guarding Conveyor Belts at Metal and Nonmetal Mines*. Mine Safety and Health Administration, 8 June 2016. PowerPoint. 10 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Examination, Testing, and Maintenance of Conveyor Belt Emergency Stop Devices under 30 C.F.R. § 77.502*. By Kevin G. Stricklin. 19 Apr. 2012. Web. 2 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Unguarded Conveyors with Adjacent Travelways*. Occupational Safety and Health Administration, 8 June 2016. Web. 10 June 2016.

Other Sources of Inspiration

International Electrotechnical Commission, *Functional Safety*, 2015

International Organization for Standardization, *ISO 13849 Safety of machinery – Safety – related parts of controls systems – Part 1: General principle for design*, 2006

Deutsches Institut Für Normung e. V., *Low-Voltage Switchgear and Controlgear – Part 5-1: Control Circuit Devices and Switching Elements – Electromechanical Control Circuit Devices*, 2010

Deutsches Institut Für Normung e. V., *Safety of Machinery – Electrical Equipment of Machines – Part 1: General Requirements*, 2007

* With the permission of Canadian Standards Association, (operating as CSA Group), material is reproduced from CSA Group standards, Z432-04 (R2014) – Safeguarding of Machinery, M421-11 (R2016) – Use of electricity in mines and M422-14 – Fire-performance and antistatic requirements for conveyor belting, which are copyrighted by CSA Group, 178 Rexdale Blvd., Toronto, ON, M9W 1R3. This material is not the complete and official position of CSA Group on the referenced subjects, which is represented solely by the standards in their entirety. While use of the material has been authorized, CSA Group is not responsible for the manner in which the data is presented, nor for any interpretations thereof. For more information or to purchase standards from CSA Group, please visit http://shop.csa.ca/ or call 1-800-463-6727.

** Used with permission from the Government of Alberta, Alberta Labour. ©Alberta Queen's Printer, 2016.

*** Reproduced by permission of DIN Deutsches Institut für Normung e.V. The definitive version for the implementation of this standard is the edition bearing the most recent date of issue, obtainable from Beuth Verlag GmbH, Burggrafenstraße 6, 10787 Berlin, Germany.

**** Reprinted from ASME B.20 1-2015, by permission of The American Society of Mechanical Engineers. All rights reserved.

Chapter 7

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – General Requirements*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. 1-86. Print.

* Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Conveyors – Belt Conveyors for Loose Bulk Materials – Basis for Calculation and Dimensioning*, English Translation of DIN 22101:2011-12. Berlin, 2011. Print.

* Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Handling Equipment and Systems – Safety and EMC Requirements for Fixed Belt Conveyors for Bulk Materials (includes Amendment A1:2010) English Translation of DIN EN 620:2011-07*. Berlin, 2011. Print.

India. Bureau of Indian Standards. *Selection and Design of Belt Conveyors Code of Practice*. New Delhi: Bureau of Indian Standards, 1986. Print.

** *Safety Standard for Conveyors and Related Equipment*. New York, NY: American Society of Mechanical Engineers, 2009. Print.

*** South Africa. South African Department of Minerals and Energy. *Mine Health and Safety Act 29 of 1996*. By Penuell Mpapa Maduna. 1996. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Loading and Haulage Equipment; Operation*. Mine Safety and Health Administration, 8 June 2016. Web. 10 June 2016.

Other Sources of Inspiration

American Society of Mechanical Engineers, *Conveyors – Cableways and Related Equipment*, 1958

Occupational Safety and Health Administration, *Conveyors*, 2016

* Reproduced by permission of DIN Deutsches Institut für Normung e.V. The definitive version for the implementation of this standard is the edition bearing the most recent date of issue, obtainable from Beuth Verlag GmbH, Burggrafenstraße 6, 10787 Berlin, Germany.

** Reprinted from ASME B.20 1-2009, by permission of The American Society of Mechanical Engineers. All rights reserved.

*** © DoC2014: ALL RIGHTS RESERVED

Chapter 8

Handbook of Conveyor and Elevator Belting. Akron: Goodyear Tire & Rubber, 2000. Print.

Chapter 9

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – Belt Conveyors for Bulk Materials Handling*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. Print.

Brazil. Brazilian Ministry of Labor & Employment. *NR22 – Safety and Occupational Health in Mining*. 1999. Print.

British Columbia. Ministry of Energy, Mines and Petroleum Resources Mining and Minerals Division. *Health, Safety, and Reclamation Code for Mines in British Columbia*. Victoria: Resource Management Branch, Ministry of Energy, Mines and Petroleum Resources, 1992. Print.

* Canada. Government of Alberta. *Occupational Health and Safety Code*. Edmonton: Alberta Queen's Printer, 2009. Print.

* Canada. Government of Alberta. *Occupational Health and Safety Code Explanation Guide*. Edmonton: Alberta Queen's Printer, 2009. Print.

Design and Safe Application of Conveyor Crossovers for Unit Handling Conveyors. 1 June 2004. Naples.

Guideline, Safety Around Belt Conveyors. Conveyor Manufacturers Association of SA. Oct. 2013. Print.

India. Bureau of Indian Standards. *Code of Recommended Practice for Conveyor Safety, Part 2: General Safety Requirements*. New Delhi: Bureau of Indian Standards, 1986. Print.

** *Safety Standard for Conveyors and Related Equipment*. New York, NY: American Society of Mechanical Engineers, 2009. Print.

South Africa. De Beers. *Mandatory Code of Practice for the Safe Use of Conveyor Belt Installations for the Transportation of Minerals, Material or Personnel*. Alldays, 2016. Print.

United States. California Department of Industrial Relations. *Subchapter 7. General Industry Safety Orders Group 6. Power Transmission Equipment, Prime Movers, Machine and Machine Parts Article 41. Prime Movers Machinery*. Web. 3 June 2016.

United States. California Department of Industrial Relations. *Subchapter 17. Mine Safety Orders Article 18. Conveyors and Tramways*. Web. 3 June 2016.

United States. California Department of Industrial Relations. *Subchapter 7. General Industry Safety Orders Group 6. Power Transmission Equipment, Prime Movers, Machine and Machine Parts Article 41. Prime Movers Machinery*. Web. 3 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Conveyor Crossovers*. Mine Safety and Health Administration, 8 June 2016. Web. 10 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Crossing Moving Conveyors*. Mine Safety and Health Administration, 8 June 2016. Web. 10 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Handrails and Toeboards*. Mine Safety and Health Administration, 8 June 2016. Web. 10 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Travelways at Surface Installations*. Mine Safety and Health Administration, 8 June 2016. Web. 10 June 2016.

United States. Utah Department of Administrative Services. *R614. Labor Commission, Occupational Safety and Health. Rule R614-5. Materials Handling and Storage*. 1 May 2016. Web. 3 June 2016.

United States. Washington State Legislature. *Install Belt Conveyor Overpasses*. 5 Jan. 2016. Web. 3 June 2016.

United States. Washington State Legislature. *Provide pedestrian overpasses for conveyors*. 5 Jan. 2016. Web. 3 June 2016.

United States. West Virginia State Legislature. *Ramps; tipples; cleaning plants; other surface areas*. 2015. Web. 3 June 2016.

* Used with permission from the Government of Alberta, Alberta Labour. ©Alberta Queen's Printer, 2016.

** Reprinted from ASME B.20 1-2009, by permission of The American Society of Mechanical Engineers. All rights reserved.

Chapter 10

Australia. *Conveyors – Safety Requirements*. Sydney: Standards Australia International, 2001. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – Belt Conveyors for Bulk Materials Handling*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of machinery Part 1601: Design of controls, interlocks and guarding – Guards – General requirements for the design and construction of fixed and moveable guards*. Sydney: SAI Global Limited, 2014. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery Part 3610: Conveyors – General requirements*. Sydney: SAI Global Limited, 2014. Print.

* Canada. Canadian Standards Association. *Z432-04 (R2014) Safeguarding of Machinery.* Toronto: Canadian Standards Association, 2004. Print.

Chain Link Fence Manufacturers Institute. *Chain Link Fence Manufacturers Institute Product Manual CLF-PM0610*. Oct. 2015. Columbia, MD.

Dreyer, E., and P. J. Nel. *Best Practice: Conveyor Belt Systems*. Marshalltown, South Africa: Anglo Technical Division, 2001. Print.

European Union. European Commission. *Guide to Application of the Machinery Directive*. 2nd ed. Luxembourg: Publications Office of the European Union, 2006. Print.

** Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Handling Equipment and Systems – Safety and EMC Requirements for*

Fixed Belt Conveyors for Bulk Materials (includes Amendment A1:2010) English Translation of DIN EN 620:2011-07. Berlin, 2011. Print.

Giraud, Laurent, Serge Massé, Julie Dubé, Luc Schreiber, and André Turcot. *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*. Mississauga, ON.: Industrial Accident Prevention Association (IAPA), 2003. Print.

Great Britain. British Standards. European Committee for Standardization. S*afety of Machinery – Safety Distances to Prevent Hazard Zones Being Reached by Upper and Lower Limbs*. Brussels, 2008. Print.

Guide to the New Machinery Directive. Leeds: Procter Machine Guarding, 2009. Print.

Lazzara, Joseph J. "Safeguarding: Future Trends in Machine Safeguarding." *EHS Today*. EHS Today, 3 Feb. 2004. Web. 13 June 2016.

Machine Guarding. Bryan: Nelson & Associates, 1995. Print.

MIOSHA. "Ergonomics." Interview. *Michigan Gov Documents*. 2 Sept. 2006. Web. 6 June 2016.

Peabody, John. "The Do's and Don'ts of Fixed and Moveable Machine Guards, Part 1." *EHS Today* 30 Nov. 2011: 1-3. Print.

Performance Requirements for Safeguarding. Washington, DC: American National Standards Institute, 2010. Print.

Proctor, Jeremy. "On Your Guard." *HSM*. HSM, 14 Nov. 2013. Web. 10 June 2016.

Procter, Jeremy. "The Differences between Guarding Standards ISO 14120 and EN 953." *Machine Building*. Machine Building, 25 Nov. 2014. Web. 20 June 2016.

** *Safety Standard for Conveyors and Related Equipment*. New York, NY: American Society of Mechanical Engineers, 2015. Print.

Sanchez, Jose. "Conveyors-Guarding Against Inadequacy." *MineSafe* Dec. 2011. Print.

Snyder, John. "Machine Guard Fastening and the New Directive." *Design, Products, and Applications* 1 June 2009: 1. Print.

United States. U.S Department of Labor. Mine Safety and Health Administration. *Construction and Maintenance of Guards*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Guarding Conveyor Belts at Metal and Nonmetal Mines*. Mine Safety and Health Administration, 8 June 2016. PowerPoint. 10 June 2016.

United States. U.S Department of Labor. Mine Safety and Health Administration. *Moving Machine Parts*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *MSHA's Guide to Equipment Guarding*. Washington, D.C.: U.S. Dept. of Labor, Mine Safety and Health Administration, 2004. Print.

United States. U.S Department of Labor. Mine Safety and Health Administration. *Overhead Drive Belts*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *General Requirements for All Machines*. Web. 3 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Mechanical Power Presses*. Web. 6 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Safeguarding Equipment and Protecting Employees from Amputations*. 17 Dec. 2015. Web. 2 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Safety Color Code for Marking Physical Hazards*. Web. 3 June 2016.

Western Australia. Department of the Premier and Cabinet. *Mines Safety and Inspection Regulations 1995*. 8 Dec. 1995. Web. 2 June 2016.

Other Sources of Inspiration

American National Standards Institute, *Mechanical Power Presses*

Australian Standard, *Safety of Machinery – Part 1801: Safety Distances to Prevent Danger Zones Being Reached by the Upper Limbs*, 2006

Canadian Centre for Occupational Health and Safety, *Calculating Recommended Weight Limit (RWL)*, 2009

Donald Vaillancourt, *A review of machine-guarding recommendations*, 1995

Japanese Standards Association, *JIS B 9711 Safety of Machinery – Minimum Gaps to Avoid Crushing of Parts of the Human Body*, 2004

Jeremy Procter, *Review: New Version of BS EN 953, Machine Guarding*, 2015

Nelson & Associates, *Machine Guarding 1946-1970*, 2010

National Safety Council, *Accident Prevention Manual for Industrial Operations*, 1974

Occupational Safety and Health Standards, *General requirements for all machines*, 2016

The American Society of Mechanical Engineers, *Safety Standard for Conveyors and Related Equipment*, 2015

Chapter 11

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery Part 3610: Conveyors – General requirements*. Sydney: SAI Global Limited, 2014. Print.

Brazil. Ministry of Labour and Employment. *NR12*. Rio De Janeiro: Brazilian Regulatory Standards on Health and Safety at Work, 2010. Print.

* Canada. Canadian Standards Association. *Z432-04 (R2014) Safeguarding of Machinery*. Toronto: Canadian Standards Association, 2004. Print.

** Canada. Government of Alberta. *Best Practices on Conveyor Safety*. Alberta Employment and Immigration, 2009. Print.

*** Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Handling Equipment and Systems – Safety and EMC Requirements for Fixed Belt Conveyors for Bulk Materials (includes Amendment A1:2010) English Translation of DIN EN 620:2011-07*. Berlin, 2011. Print.

Giraud, Laurent, Serge Massé, Julie Dubé, Luc Schreiber, and André Turcot. *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*. Mississauga, ON.: Industrial Accident Prevention Association (IAPA), 2003. Print.

Great Britain. British Standards. European Committee for Standardization. *Safety of Machinery – Safety Distances to Prevent Hazard Zones Being Reached by Upper and Lower Limbs*. Brussels, 2008. Print.

Guideline, Safety Around Belt Conveyors. Conveyor Manufacturers Association of SA. Oct. 2013. Print.

**** *Safety Standard for Conveyors and Related Equipment*. New York, NY: American Society of Mechanical Engineers, 2015. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Moving Machine Parts*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Machine Guarding*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Mechanical Power-transmission Apparatus*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

Chapter 12

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – General Requirements*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. 1-86. Print.

* Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Handling Equipment and Systems – Safety and EMC Requirements for Fixed Belt Conveyors for Bulk Materials (includes Amendment A1:2010) English Translation of DIN EN 620:2011-07*. Berlin, 2011. Print.

Giraud, Laurent, Serge Massé, Julie Dubé, Luc Schreiber, and André Turcot. *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*. Mississauga, ON.: Industrial Accident Prevention Association (IAPA), 2003. Print.

Mainline Rock and Ballast Inc v. Secretary of Labor MSHA. United States Court of Appeals, Tenth Circuit. 4 Apr. 2012. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Moving Machine Parts*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

Other Sources of Inspiration

Occupational Safety and Health Administration, *Conveyors*, 2016

Chapter 13

A Guide to Conveyor Safety. Adelaide: WorkCover Corporation, 2000. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – General Requirements*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. 1-86. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – Belt Conveyors for Bulk Materials Handling*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. 1-53. Print.

Belt Conveyors for Bulk Materials Part 1: Equipment. May 2005. National Safety Council, Itasca, IL.

Brazil. Ministry of Labour and Employment. *NR12*. Rio De Janeiro: Brazilian Regulatory Standards on Health and Safety at Work, 2010. Print.

* Canada. Ontario. *R.R.O. 1990, Reg. 854: Mines and Mining Plants*. 10 Dec. 2015. Web. 2 June 2016.

** Canada. *Regulation Respecting Occupational Health and Safety in Mines*. Québec: Éditeur Officiel Du Québec, 2015. Print.

Conveyor Terms and Definitions. Naples, FL: Conveyor Equipment Manufacturers Association, 2006. Print.

*** Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Handling Equipment and Systems – Safety and EMC Requirements for Fixed Belt Conveyors for Bulk Materials (includes Amendment A1:2010) English Translation of DIN EN 620:2011-07*. Berlin, 2011. Print.

"Hyphenated Compound Words." *English Plus*. English Plus, 2006. Web. 21 June 2016.

India. Bureau of Indian Standards. *Code of Recommended Practice for Conveyor Safety, Part 2: General Safety Requirements*. New Delhi: Bureau of Indian Standards, 1986. Print.

India. Bureau of Indian Standards. *Selection and Design of Belt Conveyors Code of Practice*. New Delhi: Bureau of Indian Standards, 1986. Print.

**** Kadakia, Mitesh. "How to Design Take-up Travel for a Fabric Conveyor Belt." *NIBA Belt Line Newsletter* Dec. 2009: 1-4. Print.

***** *Safety Standard for Conveyors and Related Equipment*. New York, NY: American Society of Mechanical Engineers, 2015. Print.

United States. Department of Licensing and Regulatory Affairs. Director's Office. *General Industry Safety Standards*. Lansing: Department of Licensing and Regulatory Affairs, 2013. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Moving Machine Parts*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. MSHA's *Guide to Equipment Guarding*. Washington, D.C.: U.S. Dept. of Labor, Mine Safety and Health Administration, 2004. Print.

* This excerpt is an unofficial version of Government of Ontario legal materials.

** Reproduced with the permission of CCOHS, 2016

*** Reproduced by permission of DIN Deutsches Institut für Normung e.V. The definitive version for the implementation of this standard is the edition bearing the most recent date of issue, obtainable from Beuth Verlag GmbH, Burggrafenstraße 6, 10787 Berlin, Germany.

**** Used with permission from NIBA – The Belting Association

***** Reprinted from ASME B.20 1-2015, by permission of The American Society of Mechanical Engineers. All rights reserved.

Chapter 14

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – General Requirements*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. 1-86. Print.

Brazil. Ministry of Labour and Employment. *NR12*. Rio De Janeiro: Brazilian Regulatory Standards on Health and Safety at Work, 2010. Print.

* Canada. Ontario. *R.R.O. 1990, Reg. 854: Mines and Mining Plants*. 10 Dec. 2015. Web. 2 June 2016.

Canada. Quebec Government. *Regulation Respecting Occupational Health and Safety in Mines*. Quebec: Éditeur Officiel Du Québec, 2016. Print.

Chain Link Fence Manufacturers Institute. *Chain Link Fence Manufacturers Institute Product Manual CLF-PM0610*. Oct. 2015. Columbia, MD.

** Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Handling Equipment and Systems – Safety and EMC Requirements for Fixed Belt Conveyors for Bulk Materials (includes Amendment A1:2010) English Translation of DIN EN 620:2011-07*. Berlin, 2011. Print.

India. Bureau of Indian Standards. *Code of Recommended Practice for Conveyor Safety, Part 2: General Safety Requirements*. New Delhi: Bureau of Indian Standards, 1986. Print.

"May the Proper Force Be With You." *Kinetics – A Part of Law Enforcement*. Cardiff Pines Corporation, 2007. Web. 13 June 2016.

Safety Standard for Conveyors and Related Equipment. New York, NY: American Society of Mechanical Engineers, 2015. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Flying or falling materials*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Conveyors*. Web. 2 June 2016.

United States. Washington State Legislature. *WAC 296-806-42020*. Washington State Legislature, 5 Jan. 2016. Web. 13 June 2016.

Other Sources of Inspiration

International Labour Organization, *Encyclopedia of Health and Safety*, 1998

* This excerpt is an unofficial version of Government of Ontario legal materials.

** Reproduced by permission of DIN Deutsches Institut für Normung e.V. The definitive version for the implementation of this standard is the edition bearing the most recent date of issue, obtainable from Beuth Verlag GmbH, Burggrafenstraße 6, 10787 Berlin, Germany.

Chapter 15

Australia. Standards Australia Limited. *Methods of Testing Conveyor and Elevator Belting – Determination of Combustion Propagation Characteristics of Conveyor Belting*. Sydney: Standards Australia International, 1996. Print.

Australia. Standards Australia Limited. *Methods of Testing Conveyor and Elevator Belting – Determination of Electrical Resistance of Conveyor Belting*. Sydney: Standards Australia International, 1982. Print.

Australia. Standards Australia Limited. *Methods of Testing Conveyor and Elevator Belting – Determination of Ignitability and Flame Propagation Characteristics of Conveyor Belting*. Sydney: Standards Australia International, 1994. Print.

Australia. Standards Australia Limited. *Methods of Testing Conveyor and Elevator Belting – Determination of Ignitability and Maximum Surface Temperature of Belting Subjected to Friction*. Sydney: Standards Australia International, 1988. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – General Requirements*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. 1-86. Print.

Belt Conveyors. Avon: Global Asset Protection Services, 2003. Print.

British Columbia. Ministry of Energy, Mines and Petroleum Resources Mining and Minerals Division. *Health, Safety, and Reclamation Code for Mines in British Columbia*. Victoria: Resource Management Branch, Ministry of Energy, Mines and Petroleum Resources, 1992. Print.

Brouwers, Styze. "If the Belt Is on Fire." *Bulk Solids Handling*. WoMa Media Dröttboom & Geisler GbR, 27 July 2015. Web. 17 Feb. 2016.

Brouwers, Sytze. "Playing with Fire?" *Dry Cargo International* Jan. 2014. Print.

* Canada. Canadian Standards Association. *M422-14 – Fire-performance and Antistatic Requirements for Conveyor Belting*. Toronto: Canadian Standards Association, 2014. Print

Candy, Geoff. "North Platinum Recovers from Fire." *Mineweb*. Mineweb, 3 Feb. 2005. Web. 23 June 2016.

China. Coal Science Research Institute Shanghai Branch. *Solid Woven Fire Resistant Conveyor Belting for Coal Mine*. Shanghai: Standardization Technical Committee of the Coal Industry, 2008. Print.

Conveyor Belt Entry Fire Hazards and Control. 12th U.S./North American Mine Ventilation Symposium. Nevada, Reno. 11 June 2008. Lecture.

"Conveyor Belt Fire in Pueblo at Comanche Power Station." *KRDO*. Pikes Peak Television, 3 June 2013. Web. 13 June 2016.

Douberly, Edward B. "Safety: Detecting Fires on PRB Coal Conveyors." *Power Magazine*. Power Magazine, 1 Nov. 2007. Web. 14 June 2016.

Dungan, K. W. *Fire Protection in Coal Handling Facilities New and Retrofit*. Boston: Society of Fire Protection Engineers, 1981. Print.

** European Union. European Commission. *Early Detection and Fighting of Fires in Belt Conveyor*. Luxembourg: Publications Office of the European Union, 2013. Print.

Fire Hazards of Belt Conveyors. Impala Park: Fire Protection Association of Southern Africa, 2000. Print.

Great Britain. Ministry of Fuel and Power. *Accident at Creswell Colliery, Derbyshire*. By Andrew Meikle Bryan. London: Her Majesty's Stationary Office, 1952. Print.

India. Bureau of Indian Standards. *Conveyor and elevator textile belting, Part 5: Fire resistant belting for surface application*. New Delhi: Bureau of Indian Standards, 1993. Print.

India. Bureau of Indian Standards. C*onveyor belts- Fire resistant conveyor belting for underground mines and such other hazardous applications*. New Delhi: Bureau of Indian Standards, 1992. Print.

*** Kadakia, Mitesh. "Conveyor Belt - New MSHA Standard." *NIBA Belt Line Newsletter* Sept. 2009: 1-2. Print.

Küsel, Bernd. "International Comparison of Fire Resistant Conveyor Belts." Pittsburgh, PA. March 2007. PowerPoint Presentation.

Le Roux, Helene. "Conveyors Come under Scrutiny after Northam Platinum Fire." *Creamer Media's Mining Weekly*. Mining Weekly, 29 Oct. 2004. Web. 13 June 2016.

MSHA B.E.L.T or Not MSHA B.E.L.T...that Is the Question? Rosemont: Fenner Dunlop, 2013. Print.

Safe Use of Belt Conveyors in Mines: Topic Report. Sudbury, England: HSE, 1993. Print.

*** "Static Electricity Considerations." *NIBA Belt Line Newsletter* 2011: 1-3. Print.

United Kingdom. *Conveyor Belts – Drum Friction Testing*. London: British Standards Institution, 2012. Print.

United States. Center for Disease Control and Prevention. *Final Report of the Technical Study Panel on the Utilization of Belt Air and the Composition and Fire Retardant Properties of Belt Materials in Underground Coal Mining*. By Jürgen F. Brune, Felipe Calizaya, Thomas P. Mucho, Jan M. Mutmansky, Jerry Chen-Jen. Tien, and James L. Weeks. Pittsburgh, PA: National Institute for Occupational Safety and Health, Office of Mine Safety and Health, 2007. Print.

United States. Center for Disease Control and Prevention. The National Institute for Occupational Safety and Health. *Mining Publication: Improvements in Conveyor Belt Fire Suppression Systems for U.S. Coal Mines*. Center for Disease Control and Prevention, 2010. Web. 29 June 2016.

United States. National Institute for Occupational Safety and Health. *Flammability of Wider Conveyor Belts Using Large-scale Fire Tests*. By J. H. Rowland and A. C. Smith. Pittsburgh: NIOSH, 2012. 1-5. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Comment from Jim Tozzi, The Center for Regulatory Effectiveness*. By Jim Tozzi. Mine Safety and Health Administration, 2008. 1-39. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Installation of Water Sprinkler Systems; Requirements*. Washington, DC: U.S. Department of Labor, 2007. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Report of Investigation Fatal Underground Coal Mine Fire*. Stollings: U.S. Department of Labor. 2007. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Type and Quality of Fire-Fighting Equipment*. Washington, DC: U.S. Department of Labor. 2007. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Water Sprinkler Fire Protection of Underground Belt Conveyors and Belt Takeup Storage Units*. By Linda F. Zeiler and Kevin G. Stricklin. Mine Safety and Health Administration, 6 May 2011. Web. 14 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Water Sprinkler Systems; Arrangement of Sprinklers*. Washington, DC: U.S. Department of Labor, 2007. Print.

United States. U.S. Department of Labor. Office of Information and Regulatory Affairs. *Flame Resistant Conveyor Belts, Fire Protection and Detection, and Use of Air From the Belt Entry*. By Marcelo M. Hirschler. Arlington: Office of Information and Regulatory Affairs, 2009. Print.

Verakis, Harry C. *Reducing the Fire Hazard of Mine Conveyor Belts*. Triadelphia: Approval and Certification Center, 1991. Print.

Yardley, E. D., and L. R. Stace. *Fire Safety Testing of Conveyor Belts*. Sudbury: HSE, 2002. Print.

Other Sources of Inspiration

ASTM International, *Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)*, 2013

Ben-Piet Terblanche, *Conveyor Belting, Solid Woven Specification*, 2009

British Standards, *Conveyor belts – Drum friction testing*, 2012

British Standards, *Conveyor belts – Electrical conductivity – Specification and test method*, 2012

British Standards, *Conveyor belts – Fire simulation flammability testing – Propane burner tests*, 2014

British Standards, *Conveyor belts – Laboratory scale flammability characteristics – Requirements and test methods*, 2013

British Standards, *Conveyor belts for general purpose use – Electrical and flammability safety requirements*, 2008

British Standards, *Conveyor belts for use in underground installations – Electrical and flammability safety requirements*, 2015

British Standards, *Steel cord conveyor belts – Special safety requirements for belts for use in underground installations*, 2007

Coal Science Research Institute Shanghai Branch, *Steel Cord Fire Resistant Conveyor Belting for Coalmine*, 2008

Deutsches Institut für Normung e.V, *Conveyor belts – Drum friction testing*, 2012

Deutsches Institut für Normung e.V, *Conveyor belts – Electrical conductivity – Specification and test method*, 2012

Deutsches Institut für Normung e.V, *Conveyor belts – Electrical conductivity – Specification and method of test*, 1993

Deutsches Institut für Normung e.V, *Conveyor belts for coal mining – Determination of the oxygen index*, 2002

Deutsches Institut für Normung e.V, *Plastics – Determination of burning behavior by oxygen index – Part 2: Ambient-temperature test*, 2006

European Parliament and Council, *The Approximation of the Laws of the Member States Concerning Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres*, 1994

FM Global, *Property Loss Prevention Data Sheets – Belt Conveyors*, 2012

International Organization for Standardization, *Conveyor belts – Specification for rubber or plastics-covered conveyor belts of textile construction for general use*, 2013

International Organization for Standardization, *Conveyor belts – Specification for rubber or plastics-covered conveyor belts of textile construction for underground mining*, 2013

International Organization for Standardization, *Plastics – Determination of burning behavior by oxygen index – Part 1: Guidance*, 1996

International Organization for Standardization, *Plastics – Determination of burning behavior by oxygen index – Part 3: Elevated-temperature test*, 1996

International Organization for Standardization, *Steel cord conveyor belts – Part 3: Special safety requirements for belts for use in underground installations*, 2007

Mine Safety and Health Administration, *Application Procedures for Acceptance of Flame-Resistant Solid Products Taken Into Mines*, 2010

Mine Safety and Health Administration, *Conveyor Belt Combustion Toxicity and Smoke Density*, 2008

Mine Safety and Health Administration, *Electrical Testing Study Material*, 1992

Mine Safety and Health Administration, *Mineral Resources*, 2014

Mine Safety and Health Administration, *MSHA's Standard Flame Test Procedure for: Hose Conduit, Fire Suppression Hose Cover, Fire Hose Liner and Other Materials; Title 30, Code of Federal Regulations, Part 18, Section 18.65*, 2010

Mine Safety and Health Administration, *Safety Standards Regarding the Recommendations of the Technical Study Panel on the Utilization of Belt Air and the Composition and Fire Retardant Properties of Belt Materials in Underground Coal Mining*, 2008

Mining Enforcement and Safety Administration, *Federal Coal Mine Health and Safety Act of 1969*, 1969

National Coal Board, *NCB 158*, 1954

National Fire Protection Association, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*, 2015

National Fire Protection Association, *Standard for Fire Prevention and Control in Coal Mines*, 2015

National Fire Protection Association, *Standard for the Installation of Sprinkler Systems*, 2016

National Fire Protection Association, *Standard for the Prevention of Fire and Dust Explosions from Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2013

National Fire Protection Association, *Standard on the Fundamentals of Combustible Dust*, 2016

National Fire Protection Association, *Standard for Water Spray Fixed Systems for Fire Protection*, 2012

Occupational Safety and Health Standards, *Grain Handling Facilities*, 2016

South African National Standards, *Conveyor belts – Laboratory scale flammability characteristics – Requirements and test method*, 2013

South African National Standards, *General Purpose Textile-Reinforced Conveyor Belting*, 2006

South African National Standards, *Methods of testing fire-retardant properties of all conveyor belt constructions*, 2013

South African National Standards, *Steel Cord Reinforced Conveyor Belting*, 2006

Standards Australia, *Fire resistant and antistatic requirements for conveyor belting used in underground coal mines*, 2000

Standards Australia, *Grade S fire resistant and antistatic requirements for conveyor belting and conveyor accessories*, 2012

Wikipedia, *List of fire-retardant materials*, 2016

* With the permission of Canadian Standards Association, (operating as CSA Group), material is reproduced from CSA Group standards, Z432-04 (R2014) – Safeguarding of Machinery, M421-11 (R2016) – Use of electricity in mines and M422-14 – Fire-performance and antistatic requirements for conveyor belting, which are copyrighted by CSA Group, 178 Rexdale Blvd., Toronto, ON, M9W 1R3. This material is not the complete and official position of CSA Group on the referenced subjects, which is represented solely by the standards in their entirety. While use of the material has been authorized, CSA Group is not responsible for the manner in which the data is presented, nor for any interpretations thereof. For more information or to purchase standards from CSA Group, please visit http://shop.csa.ca/ or call 1-800-463-6727.

** This Early Detection and Fighting of Fires in Belt Conveyors project did not receive funding from the Research Fund for Coal and Steel of the European Union, nor is the European Commission responsible for any use of the information contained in this report.

*** Used with permission from NIBA – The Belting Association

Chapter 16

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Interior Lighting Part 2.4: Industrial Tasks and Processes*. Sydney: Standards Australia Limited / Standards New Zealand, 1997. 1-56. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – Belt Conveyors for Bulk Materials Handling*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – General Requirements*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. 1-86. Print.

British Columbia. Ministry of Energy, Mines and Petroleum Resources Mining and Minerals Division. *Health, Safety, and Reclamation Code for Mines in British Columbia*. Victoria: Resource Management Branch, Ministry of Energy, Mines and Petroleum Resources, 1992. Print.

* Canada. Ontario. *R.R.O. 1990, Reg. 851: Industrial Establishments*. 10 Dec. 2015. Web. 2 June 2016.

Charpentier, Will. "Factory Lighting Regulations." *Small Business*. StudioD, 2016. Web. 14 June 2016.

Fruchtbaum, Jacob. *Bulk Materials Handling Handbook*. New York City: Springer, 2014. Print.

India. Bureau of Indian Standards. *Code of Practice for Interior Illumination*. New Delhi: Bureau of Indian Standards, 1994. Print.

NEMA Enclosure Types. Rosslyn: National Electrical Manufacturers Association, 2005. Print.

Smith, Bruce W. "Developing a New Temporary Lighting System: From Identification of the Problem to the Design of the Solution." Web. 6 June 2016.

South Africa. De Beers. *Mandatory Code of Practice for the Safe Use of Conveyor Belt Installations for the Transportation of Minerals, Material or Personnel*. Alldays, 2016. Print.

United States. Michigan Occupational Safety and Health Administration. General Industry Safety & Health Division. *General Industry Safety Standards*. Lansing: MIOSHA, 2011. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Illumination of Surface Working Areas*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *1926.56*. By Patricia K. Clark and Madelynn R. Kirkpatrick. 8 May 1991. Web. 6 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Illumination*. 23 Oct. 2015. Web. 2 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Maintenance, Safeguards, and Operational Features for Exit Routes*. 7 Nov. 2002. Web. 6 June 2016.

United States. Utah Department of Administrative Services. *R614. Labor Commission, Occupational Safety and Health. Rule R614-5. Materials Handling and Storage*. 1 May 2016. Web. 3 June 2016.

United States. Washington State Legislature. *Provide and Maintain Adequate Lighting*. 2003. Web. 3 June 2016.

Other Sources of Inspiration

American National Standards Institute, *Practice for Industrial Lighting*, 1970

American National Standards Institute, *Recommended Practice for Office Lighting Training*, 2004

Australian Standard/New Zealand Standard, *Interior and Workplace Lighting – Circulation Spaced and Other General Areas*, 2008

Australian Standard/New Zealand Standard, *Interior and Workplace Lighting – General Principles and Recommendations*, 2006

Australian Standard/New Zealand Standard, *Interior and Workplace Lighting – Office and Screen-Based Tasks*, 2008

Australian Standard/New Zealand Standard, *Interior Lighting – Educational and Training Facilities*, 2008

Australian Standard/New Zealand Standard, *Interior Lighting – Hospital and Medical Tasks*, 1997

Australian Standard/New Zealand Standard, *Interior Lighting – Industrial Tasks and Processes*, 1997

Australian Standard/New Zealand Standard, *Interior Lighting – Safe Movement*, 2009

British Standards Institute, *Light and Lighting – Lighting of Work Places – Indoor Work Places*, 2011

Commission Internationale de l'Eclairage, *Lighting Energy Standards and Codes*, 2001

Indian Standard, *Code of Practice for Interior Illumination*, 1994

Indian Standard, *National Building Code of India* 2005, 2005

International Commission on Illumination, *Guide on Interior Lighting*, 1986

International Organization for Standardization, *Safety of Machinery – Permanent Means of Access to Machinery – Part 1: Choice of Fixed Means and General Requirements of Access*, 2016

International Organization for Standardization, *Safety of Machinery – Permanent Means of Access to Machinery – Part 2: Working Platforms and Walkways*, 2016

International Organization for Standardization, *Safety of Machinery – Permanent Means of Access to Machinery – Part 3: Stairs, Stepladders and Guard-Rails*, 2016

International Organization for Standardization, *Safety of Machinery – Permanent Means of Access to Machinery – Part 4: Fixed Ladders*, 2004

International Standards Organization, *Lighting of Work Places – Part 1: Indoor*, 2001

National Electrical Manufacturers Association, *Degrees of Protection Provided by Enclosures (IP Code) (identical national adoption)*, 2004

People's Republic of China Industry Standard, *Architectural Lighting Design Standards*, 2013

Russian Federation of Building Regulations, *Daylight and Artificial Lighting*, 2010

South African Bureau of Standards, *Interior Lighting – Part 1: Artificial Lighting of Interiors*, 2010

* This excerpt is an unofficial version of Government of Ontario legal materials.

Chapter 17

British Columbia. Ministry of Energy, Mines and Petroleum Resources Mining and Minerals Division. *Health, Safety, and Reclamation Code for Mines in British Columbia*. Victoria: Resource Management Branch, Ministry of Energy, Mines and Petroleum Resources, 2008. Print.

British Columbia. Victoria: Resource Management Branch, Ministry of Energy, Mines and Petroleum Resources, 1992. Print.

* Canada. Government of Alberta. *Occupational Health and Safety Code*. Edmonton: Alberta Queen's Printer, 2009. Print.

Canada. Quebec Government. *Regulation Respecting Occupational Health and Safety in Mines*. Éditeur Officiel Du Québec, 2016. 1-134. Print.

Cecala, Andrew B. *Dust Control Handbook for Industrial Minerals Mining and Processing*. Pittsburgh: NIOSH, 2012. Print.

** Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Handling Equipment and Systems – Safety and EMC Requirements for Fixed Belt Conveyors for Bulk Materials (includes Amendment A1:2010) English Translation of DIN EN 620:2011-07*. Berlin, 2011. Print.

Michael Best & Friedrich LLP. "Combustible Dust: Complying with OSHA Regulations and Preventing the Hazards of Combustible Dust." *Michael Best & Friedrich LLP*. Michael Best & Friedrich LLP, 18 June 2008. Web. 16 June 2016.

South Africa. Southern African Legal Information Institute. *The 2007 National Framework for Air Quality Management in the Republic of South Africa*. Pretoria: Department of Environmental Affairs and Tourism, 2007. Print.

Switzerland. World Health Organization. *Hazard Prevention and Control in the Work Environment: Airborne Dust*. Geneva: World Health Organization, 1999. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Exposure Limits for Airborne Contaminants*. 7 Nov. 2008. Web. 6 June 2016.

Other Sources of Inspiration

ASTM International, *Standards Test Method for Collection and Measurement of Dustfall (Settleable Particulate Matter)*, 1998

Deutsches Institut Für Normung e. V., *Ambient Air – Standard Gravimetric Measurement Method for the Determination of the PM <(Index)10> or PM <(Index)2,5> Mass Concentration of Suspended Particulate Matter*, 2014

Greg Chekan, *Best Practices for Dust Control in Metal/Nonmetal Underground Mining*

Italian Organization for Standardization, *Ambient Air Quality – Standard Gravimetric Measurement Method for the Determination of the Pm[2,5] Mass Fraction of Suspended Particulate Matter*, 2005

International Electrotechnical Commission, *Electrical apparatus for use in the presence of combustible dust – Part 1-1: Electrical apparatus protected by enclosure and surface temperature limitation – Specification for apparatus*, 1999

National Fire Protection Association, *NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2013

National institute for Occupational Safety and Health, *Best Practices for Dust Control in Coal Mining*, 2010

National Institute for Occupational Safety and Health, *Dust Control Handbook for Industrial Minerals Mining and Processing*, 2012

Occupational Safety and Health Administration, *Electric Power Generation, Transmission, and Distribution*, 2016

Occupational Safety and Health Administration, *Grain Handling Facilities*, 2016

Occupational Safety and Health Administration, *Hazard Communication*, 2016

Occupational Safety and Health Administration, *Hazardous (classified) Locations*, 2016

Safe Work Australia, *Workplace Exposure Standards for Airborne Contaminants*, 2013

South African Bureau of Standards, *Ambient air quality – Limits for common pollutants*, 2011

Standards Australia, *Workplace atmospheres – Method for sampling and gravimetric determination of inhalable dust*, 2009

Standards Australia, *Workplace atmospheres – Method for sampling and gravimetric determination of respirable dust*, 2009

* Used with permission from the Government of Alberta, Alberta Labour. ©Alberta Queen's Printer, 2016.

** Reproduced by permission of DIN Deutsches Institut für Normung e.V. The definitive version for the implementation of this standard is the edition bearing the most recent date of issue, obtainable from Beuth Verlag GmbH, Burggrafenstraße 6, 10787 Berlin, Germany.

Chapter 18

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – General Requirements*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. 1-86. Print.

British Columbia. Ministry of Energy, Mines and Petroleum Resources Mining and Minerals Division. *Health, Safety, and Reclamation Code for Mines in British Columbia*. Victoria: Resource Management Branch, Ministry of Energy, Mines and Petroleum Resources, 2008. Print.

Canada. Quebec Government. *Regulation Respecting Occupational Health and Safety in Mines*. Éditeur Officiel Du Québec, 2016. 1-134. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Metal / Nonmetal Serious Injury Accident*. Mine Safety and Health Administration. 2015. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Safe Access*. Mine Safety and Health Administration. 2016. Web. 7 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Guarding Floor and Wall Openings and Holes*. Occupational Safety and Health Administration. 10 Feb. 1984. Web. 7 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Permit-required Confined Spaces*. Occupational Safety and Health Administration. 19 Nov. 2015. Web. 2 June 2016.

Other Sources of Inspiration

American National Standards Institute, *American National Standard Safety Requirements for Workplace Walking/Working Surfaces and Their Access; Workplace, Floor, Wall and Roof Openings; Stairs and Guardrails Systems*, 2007

American National Standards Institute, *Test Method for Determining the Impact on Wet Dynamic Coefficient of Friction of Various Chemical or Physical Walkway Surface Treatments*, 2012

American *National Standards Institute, Test Method for Measure Wet SCOF of Common Hard Surface Floor Materials*, 2009

Mine Safety and Health Administration, *Travelways*, 2016

Standards Australia, *Fixed platforms, walkways, stairways and ladders – Design, construction and installation*, 2013

Standards Australia, *Safety of Machinery – Human body measurements – Principles for determining the dimensions required for openings for whole body access into machinery*, 2006

Standards Australia, *Safety of machinery – Principles for determining the dimensions required for access openings*, 2006

Chapter 19

Brown, S. C. "Conveyor Noise Specification and Control." *Proceedings of Acoustics 2004*. Australian Acoustical Society, 5 Nov. 2004. Web. 16 June 2016.

Cohen, Alexander. *Industrial Noise and Medical, Absence, and Record Data on Exposed Workers*. Cincinnati: National Institute for Occupational Safety and Health, 1973. Print.

European Union. European Parliament. *Minimum Health and Safety Requirements Regarding the Exposure of Workers to the Risks Arising from Physical Agents (Noise)*. Strasbourg: European Parliament, 2003. Print.

Gladysiewicz, Adam. "Noise Emissions of Belt Conveyors." *Coal International* July-Aug. 2011: 44-45. Print.

Morgan, Steve. "Applications of Noise Control in the Mining Industry." *Sound Waves* Jan. 2015: 3. Print.

Munzenberger, Paul, and Craig Wheeler. *The Influence of 'maximum Indicated Slope' and 'total Indicated Run-out' on the Noise Caused by the Interaction of Conveyor Idler Rolls and Conveyor Belts*. Australia, Callaghan.

"Noise and Your Rollers." *In Sights*. Flexco, 2011. Web. 23 June 2016.

Nordell, Lawerance K. "Improving Belt Conveyor Efficiencies: Power, Strength and Life." *Conveyor Dynamics. Inc*. Conveyor Dynamics. Inc., Apr. 1998. Web. 16 June 2016.

Sensogut, C. "Occupational Noise in Mines and Its Control – A Case Study." *Polish Journal of Environmental Studies* 16.6 (2007): 939-42. Web. 16 June 2016.

South Africa. South African Department of Minerals and Energy. *Mine Health and Safety Act 29 of 1996*. By Penuell Mpapa Maduna. 1996. Print.

United Nations. World Health Organization. *Occupational Exposure to Noise: Evaluation, Prevention and Control*. Geneva: World Health Organization, 1995. Print.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Occupational Noise Exposure*. 23 Oct. 2015. Web. 2 June 2016.

United States. *Mineral Resources 30*. Vol. 1. Washington: Office of the Federal Register National Archives and Records Administration, 1999. Print.

Van Der Merwe, Barend. *Environmental Noise and Vibration Impact Assessment for The Proposed Arnot Mooifontein Opencast Expansion Project onto Portions*. Johannesburg: DBAcoustics, 2010. Print.

Van Zul, Ben. *Overland Conveyor Noise: Engineering Tools for Noise Reduction*. 2013. South Africa, Acusolv.

Western Australia. *Environmental Protection (Noise) Regulations*. Perth: Government of Western Australia, 2007. Print.

Witt, Brad. Sound Source: Changes in EU Noise Directive. *HearForever*. Honeywell International, Inc, 2013. Web. 07 June 2016.

Other Sources of Inspiration

Noise Help, *Noise!*, 2010

OSHA Europa, *Directive 2003/10/EC – Noise*, 2016

South African Bureau of Standards, *The Measurement and Rating of Environmental Noise with Respect to Annoyance and to Speech Communication*, 2008

Chapter 20

CEMA. *CEMA*. 2016. Web. 07 June 2016.

Cooper, Jonathan R., and Arun J. Kottha. "Conflicting Issues Regarding Warning Labels May Be Hazardous to Your Company's Health." *In-House Defense Quarterly* Spring 2011: 36-39. Print.

Safety Alerting Standards. Washington, DC: American National Standards Institute, 2011. Print.

European Union. *Minimum Requirements for the Provision of Safety And/or Health Signs at Work*. Luxembourg: Publications Office of the European Union, 1992. Print.

Gough, Darren. "Safety Sign Classification and Use." *Australian Safety Signs*. StikyStuf, 1 June 2014. Web. 16 June 2016.

Green, Marc. The Psychology of Warnings. *Visual Expert*. 2013. Web. 07 June 2016.

Lawton, Paul. "7 Steps for Effective Safety Signage." *EHS Daily Advisor*. EHS Daily Advisor, 10 Mar. 2014. Web. 16 June 2016.

New OSHA/ANSI Safety Sign Systems for Today's Workplaces. Milford: Clarion Safety Systems, 2013. Print.

Safety Signs and Signals: The Health and Safety (Safety Signs and Signals) Regulations 1996: Guidance on Regulations. 1st ed. Crown, 1996. Print.

"SafeTSigns at the Workplace." *South African Symbolic Safety Signs*. Foresight Publications, 16 June 2016. Web. 16 June 2016.

United States. Department of Labor. Occupational Safety and Health Administration. *Specifications for Accident Prevention Signs and Tags*. Occupational Safety and Health. 2016. Web. 7 June 2016.

Other Sources of Inspiration

American National Standard, *Safety Alerting Standards*, 2011

American National Standards Institute, *Silently Guiding Safety: American National Standards for Safety Signs and Colors*, 2011

Conveyor Equipment Manufacturers Association, *CEMA Safety Information – Safety Labels*, 2006

International Standards Organization, *Graphic symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*, 2011

Standards Australia, *Safety signs for the occupational environment*, 1994

Standards Council of Canada, *Signs and Symbols for the Workplace*, 2006

Chapter 21

Campbell, Richard B., ScD, and David A. Dini, P.E. *Occupational Injuries from Electrical Shock and Arc Flash Events*. Quincy: Fire Protection Research Foundation, 2015. Print.

National Lighting Safety Institute. *Lighting Safety in the Mining Industry*. Dec. 2013.

New Zealand. Department of Labour. Occupational Safety & Health. *Guidelines for the Control of Static Electricity in Industry*. Wellington: Occupational Safety & Health, 1990. Print.

O'Connor, Joe. "Fire in the Workplace." *Electrical Contractor Magazine*. EC Mag, Jan. 2004. Web. 29 June 2016.

Petkovske, John. "Five Potential Welding Safety Hazards to Avoid." *Lincoln Electric The Welding Experts*. The Lincoln Electric Company, 2016. Web. 23 June 2016.

R. Stahl. *The Basics of Dust-Explosion Prevention*. Waldenburg: Federal Republic of Germany, 2004. Print.

"Safety Tips to Help Avoid Industrial Electrical Injuries." *Reliable Plant News Wires*. Reliable Plant. Web. 17 June 2016.

* "Static Electricity Considerations." *NIBA - The Belting Association*. NIBA – The Belting Association, 2011. Web. 17 June 2016.

"The Dangers of Arc Flash Incidents." *Maintenance Technology*. Maintenance Technology, Feb. 2004. Web. 17 June 2016.

United States. U. S. Department of Labor. Mine Safety and Health Administration. *Distribution Boxes*. U.S. Government Publishing Office, 15 June 2016. Web 17 June 2016.

United States. U. S. Department of Labor. Mine Safety and Health Administration. *Work on Electrically-Powered Equipment*. U.S. Government Publishing Office, 15 June 2016. Web 17 June 2016.

United States. U. S. Department of Labor. Mine Safety and Health Administration. *Work on Power Circuits*. U.S. Government Publishing Office, 15 June 2016. Web 17 June 2016.

"What Is Arc Flash?" *National Electrical Code: Internet Connection*. Mike Holt Enterprises, 2004. Web. 17 June 2016.

Other Sources of Inspiration

Brazilian Regulatory Standards on Health and Safety at Work, *NR10 – Safety in Electrical Installations and Services*, 2004

British Standards, *Operation of Electrical Installations – General Requirements*, 2013

Bruce Bowman, *NFPA 70E Electrical Safety Presentation*, 2012

Canadian Standards Association, *Canadian Electrical Code, Part 1, Safety Standard for Electrical Installations*, 2015

Canadian Standards Association, *Workplace Electrical Safety*, 2015

Code of China, *Safety Code of Electric Power Industry – Electric Part of Power Plants and Transformer Substations*, 2001

European Parliament, *Directive 2006/95/EC – Electrical Equipment*, 2006

Government of Canada: Queen's Printer, *Safety Standards Act [SBC 2003] Chapter 39*, 2016

Government of South Australia, *National Electricity Act*, 1996

IEEE Standards Association, *National Electrical Safety Code*, 2016

Mine Safety and Health Administration, *Public Law 91-173*, 1977

National Fire Protection Association, *National Electrical Code*, 2014

Occupational Safety and Health Administration, *Public Law 91-596*, 2004

Standards Australia / Standards New Zealand, *Electrical Installations (Australian / New Zealand Wiring Rules)*, 2007

Standards Australia / Standard New Zealand, *Electrical Installations – Verification Guidelines*, 2007

Standards Australia / Standard New Zealand, *In-Service Safety Inspection and Testing of Electrical Equipment*, 2010

W. Keith Switzer, *Practical Guide to Electrical Grounding*, 1999

* Used with permission from NIBA – The Belting Association

Chapter 22

Anglo Technical Division. *Best Practice: Conveyor Belt Systems*. July 2001. South Africa.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – Belt Conveyors for Bulk Materials Handling*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. Print.

Belt Conveyors. *LII / Legal Information Institute*. Cornell University Law School. Web. 07 June 2016.

* Canada. Government of Alberta. *Occupational Health and Safety Code*. Edmonton: Alberta Queen's Printer, 2009. Print.

* Canada. Government of Alberta. *Occupational Health and Safety Code Explanation Guide*. Edmonton: Alberta Queen's Printer, 2009. Print.

Hughes, C. P. *An Overview of the Installation of the First Man-Riding Belt Conveyor in a South African Gold Mine*. Marshalltown: AVGOLD, 2000. Print.

** Moller, W., and E. R. Ascui. *International Materials Handling Conference*. Beltcon 5. Johannesburg,1989. Print.

Safe Use of Belt Conveyors in Mines: Topic Report. Sudbury, England: HSE, 1993. Print.

*** *Safety Standard for Conveyors and Related Equipment*. New York, NY: American Society of Mechanical Engineers, 2009. Print.

South Africa. South African Department of Minerals and Energy. *Mine Health and Safety Act 29 of 1996*. By Penuell Mpapa Maduna. 1996. Print.

Underground Transport in Coal Mines: Information Symposium, Luxembourg, May 24 to 26, 1978. Vol. 2. Redhill: Colliery Guardian, 1978. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Transporting Persons*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

Wing, S. P. "Manriding Conveyor." *HSE*. Health and Safety Executive, 2016. Web. 17 June 2016.

Wing, S. P. "Manriding Conveyor 2." *HSE*. Health and Safety Executive, 2016. Web. 17 June 2016.

Other Sources of Inspiration

E. D. Yardley and L. R. Stace, *Belt Conveying of Minerals*, 2008

South African Bureau of Standards, *The Safe Use, Operation and Inspection of Man-Riding Belt Conveyors in Mines*, 2013

E.D. Yardley, *Belt Conveying of Minerals*, 2008

* Used with permission from the Government of Alberta, Alberta Labour. ©Alberta Queen's Printer, 2016

** This paper was first presented at Beltcon 5 in 1989 and copyright is vested with IMHC (www.beltcon.org.za)

*** Reprinted from ASME B.20 1-2009, by permission of The American Society of Mechanical Engineers. All rights reserved.

Chapter 23

30 CFR 56.12016 – Work on Electrically-powered Equipment. *LII / Legal Information Institute*. Mine Safety and Health Administration. 2016. Web. 07 June 2016.

30 CFR 56.14105 – Procedures during Repairs or Maintenance. *LII / Legal Information Institute*. Mine Safety and Health Administration. Web. 07 June 2016.

Belt Conveyors for Bulk Materials Part 2: Operations. May 2005. National Safety Council, Itasca, IL.

Brazil. Brazilian Ministry of Labor & Employment. *NR22 - Safety and Occupational Health in Mining*. 1999. Print.

Brazil. Ministry of Labour and Employment. *NR12*. Rio De Janeiro: Brazilian Regulatory Standards on Health and Safety at Work, 2010. Print.

Canada. Government of Alberta. *Best Practices on Conveyor Safety*. Alberta Employment and Immigration, 2009. Print.

* Canada. Ontario. *R.R.O. 1990, Reg. 854: Mines and Mining Plants*. 10 Dec. 2015. Web. 2 June 2016.

Conveyor Safety Checklist. Washington, DC: Institute of Scrap Recycling Industries, 2011. Print.

Galleguillos, Rene. "Predictive Maintenance Strategy for Increasing the Life of Conveyor Systems." IV Congress on Conveyor Belts. Peru. Nov. 2015. Lecture.

** Germany. DIN Deutsches Institut Für Normung E. V. *Continuous Handling Equipment and Systems – Safety and EMC Requirements for Fixed Belt Conveyors for Bulk Materials (includes Amendment A1:2010) English Translation of DIN EN 620:2011-07*. Berlin, 2011. Print.

Giraud, Laurent, Serge Massé, Julie Dubé, Luc Schreiber, and André Turcot. *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*. Mississauga, ON.: Industrial Accident Prevention Association (IAPA), 2003. Print.

Guideline, Safety Around Belt Conveyors. Conveyor Manufacturers Association of SA. Oct. 2016. Print.

Lazzara, Joseph. "New Lockout/Tagout Standard Details Ways to Better Safety." *EHS Today*. EHS Today, 14 July 2004. Web. 17 June 2016.

*** Normanton, James, and Kris Porter. "Basic Conveyor Safety." *NIBA Belt Line Newsletter* Sept. 2006: 1-2. Print.

"Relationship of 1910.147, The Control of Hazardous Energy (Lockout/Tagout) Standard, to Subpart O, Machinery and Machine Guarding Standards." *Lockout-Tagout*. Occupational Health and Safety Administration, Feb. 2008. Web. 07 June 2016.

**** *Safety Standard for Conveyors and Related Equipment*. New York, NY: American Society of Mechanical Engineers, 2009. Print.

South Africa. De Beers. *Mandatory Code of Practice for the Safe Use of Conveyor Belt Installations for the Transportation of Minerals, Material or Personnel*. Alldays, 2016. Print.

South Africa. South African Department of Minerals and Energy. *Mine Health and Safety Act 29 of 1996*. By Penuell Mpapa Maduna. 1996. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Accumulation of Combustible Materials and Rock Dust*. Mine Safety and Health Administration, 21 Sept. 2010. Web. 7 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Conveyor Startup Fatalities*. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Machinery and equipment; operation and maintenance*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *U. S. Department of Labor MSHA's Accident Prevention Safety Idea*. Mine Safety and Health Administration. Print.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Conveyors*. Web. 2 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *The Control of Hazardous Energy (lockout/tagout)*. Occupational Safety and Health Administration. Web. 7 June 2016.

Other Sources of Inspiration

American National Standards Institute, *Control of Hazardous Energy – Lockout/Tagout & Alternative Methods*, 2003

Canadian Standards Association, *Control of Hazardous Energy – Lockout and Other Methods*, 2013

Consultant's Health & Safety Forum, *Safe By Design FAQs*, 2012

Tenova, *Safety First: Bastic Safety Rules*, 2014

* This excerpt is an unofficial version of Government of Ontario legal materials.

** Reproduced by permission of DIN Deutsches Institut für Normung e.V. The definitive version for the implementation of this standard is the edition bearing the most recent date of issue, obtainable from Beuth Verlag GmbH, Burggrafenstraße 6, 10787 Berlin, Germany.

*** Used with permission from NIBA – The Belting Association

**** Reprinted from ASME B.20 1-2009, by permission of The American Society of Mechanical Engineers. All rights reserved.

Chapter 24

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – Belt Conveyors for Bulk Materials Handling*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. Print.

Australia / New Zealand. Standards Australia Limited / Standards New Zealand. *Safety of Machinery – Conveyors – General Requirements*. Sydney: Standards Australia Limited / Standards New Zealand, 2015. 1-86. Print.

Belt Conveyors for Bulk Materials Part 2: Operations. May 2005. National Safety Council, Itasca, IL.

Brazil. Brazilian Ministry of Labor & Employment. *NR22 Safety and Occupational Health in Mining*. 1999. Print.

British Columbia. Ministry of Energy, Mines and Petroleum Resources Mining and Minerals Division. *Health, Safety, and Reclamation Code for Mines in British Columbia*. Victoria: Resource Management Branch, Ministry of Energy, Mines and Petroleum Resources, 1992. Print.

Canada. Government of Canada. Canadian Centre for Occupational Health and Safety. *OSH Answers Fact Sheets*. Canadian Centre for Occupational Health and Safety, 1 Mar. 2011. Web. 23 June 2016.

* Canada. Ontario. *R.R.O. 1990, Reg. 854: Mines and Mining Plants*. 10 Dec. 2015. Web. 2 June 2016.

Canada. *Regulation Respecting Occupational Health and Safety in Mines*. Québec: Éditeur Officiel Du Québec, 2015. Print.

Giraud, Laurent. *Sécurité Des Convoyeurs À Courroie: Généralités, Protection Contre Les Phénomènes Dangereux: Guide De L'utilisateur*. Montréal: Institut De Recherche, 2003. Print.

Good, E. T. *Cassier's Engineering Monthly*. Vol. 52. New York: Wendell Lansing, 1917. Print.

Guideline, Safety Around Belt Conveyors. Conveyor Manufacturers Association of SA. Apr. 2016. Print.

Guidelines for Shovel Design and Use. Mining and Quarrying Occupational Health and Safety Committee. Print.

"Quick Facts." *National Floor Safety Institute*. National Floor Safety Institute, 2016. Web. 23 June 2016.

Papard, Phil. "Improving the Management of Health and Safety in the Quarrying Industry." *Quarry Management* Mar. 1994: 27. Print.

** *Safety Standard for Conveyors and Related Equipment*. New York, NY: American Society of Mechanical Engineers, 2009. Print.

Skid Steer Loaders. Lincoln: University of Nebraska Lincoln, 2009. Print.

South Africa. De Beers. *Mandatory Code of Practice for the Safe Use of Conveyor Belt Installations for the Transportation of Minerals, Material or Personnel*. Alldays, 2016. Print.

South Africa. South African Department of Minerals and Energy. *Mine Health and Safety Act 29 of 1996*. By Penuell Mpapa Maduna. 1996. Print.

United States. Department of Labor. Mine Safety and Health Administration. *Accumulation of Combustible Materials and Rock Dust*. 21 Sept. 2010. Web. 7 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Housekeeping*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Manual cleaning of conveyor pulleys*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Travelways at surface installations*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

United States. Department of Labor. Occupational Safety and Health Administration. *General Requirements*. Occupational Safety and Health Administration. Web. 7 June 2016.

United States. Department of Labor. Occupational Safety and Health Administration. *Walking / Working Surfaces*. 19 Nov. 2015. Web. 2 June 2016.

United States. U.S. Government Publishing Office. *Mineral Resources*. U.S. Government Publishing Office, 1 June 2016. Web. 3 June 2016.

* This excerpt is an unofficial version of Government of Ontario legal materials.

** Reprinted from ASME B.20 1-2015, by permission of The American Society of Mechanical Engineers. All rights reserved.

Chapter 25

30 CFR 56.14105 - Procedures during Repairs or Maintenance. *LII / Legal Information Institute*. N.p., n.d. Web. 07 June 2016.

* Canada. Ontario. R.R.O. 1990, *Reg. 851: Industrial Establishments*. 10 Dec. 2015. Web. 2 June 2016.

Clamps for Belt Conveyors. Conveyor Manufacturers Association of SA. Oct. 2013. Print.

** Exton, Alan. *Non-Gravity Take-Up Technology*. Johannesburg: Belt Con, 2004. Belt Con, 2004. Web. 27 June 2016.

Guideline, Safety Around Belt Conveyors. Conveyor Manufacturers Association of SA. Oct. 2013. Print.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Slings*. U.S. Department of Labor, 8 June 2011. Web. 7 June 2016.

Other Sources of Inspiration

ASTM International, *Standard Specification for Grade 80 and Grade 100 Alloy Steel Chain slings for Overhead Lifting*, 2010

American Society of Mechanical Engineers, B30.9, 2014

Occupational Safety and Health Administration, *Slings*, 2011

* This excerpt is an unofficial version of Government of Ontario legal materials.

** This paper was first presented at Beltcon 17 in 2004 and copyright is vested with the IMHC (www.beltcon.org.za)

Chapter 26

"CART Receives Grant from MSHA." *Center for Applied Research and Technology, Inc*. Center for Applied Research and Technology, Inc, 24 Sept. 2010. Web. 24 June 2016.

Dalto, Jeffrey. "What Is MSHA Part 46? Training Requirements for Surface Mines." *Convergence Training*. Convergence Training, 9 Apr. 2015. Web. 23 June 2016.

Giraud, Laurent, Serge Massé, Julie Dubé, Luc Schreiber, and André Turcot. *A User's Guide to Conveyor Belt Safety: Protection from Danger Zones*. Mississauga, ON: Industrial Accident Prevention Association (IAPA), 2003. Print.

Goldbeck, Larry. "Training Employees to Operate and Maintain Conveyors Improves Efficiency of Both the Belt and the Operation." *Aggregates Manager* Oct. 2003: 1-3. Print.

India. Bureau of Indian Standards. *Code of Recommended Practice for Conveyor Safety, Part 2: General Safety Requirements*. New Delhi: Bureau of Indian Standards, 1986. Print.

Koppel, Julie. *Training Best Practices and Guidelines*. Santa Barbara: U of California, 2011. Print.

Lehmann, Carolyn C., Joel M. Haight, and Judd H. Michael. "Effects of Safety Training on Risk Tolerance: An Examination of Male Workers in the Surface Mining Industry." *Journal of SH&E Research* 4.3 (2009): 1-22. Print.

Lucas, Jason David. *Improving Conveyor Belt Safety Training through the Use of Virtual Reality*. Thesis. Virginia Polytechnic Institute and State University, 2008. Blacksburg: Virginia Polytechnic Institute and State U, 2008. Print.

McGuire, Joseph P., and Billy Snead. "The Bar Has Been Raised." *Rock Products* Aug. 2014: 20-22. Print.

McGuire, Joseph P., and Billy Snead. "The Bar Has Been Raised (Part 2)." *Rock Products* Sept. 2014: 20-22. Print.

Salas, Eduardo, P.h.D. "Patient Safety Training Evaluations: Reflections on Level 4 and More." 2009 Annual Conference. Department of Psychology & Institute of Simulation & Training at University of Central Florida, Orlando. 2009. Lecture.

United States. U.S. Bureau of Labor Statistics. *Economic News Release: Percent of Total Training Hours Spent in Various Types of Formal Training by Industry Division, May-October 1995*. Washington, DC: U.S. Bureau of Labor Statistics, 1995. Print.

United States. U.S. Department of Labor. Mine Safety and Health Administration. *Definitions*. U.S. Government Publishing Office, 29 Apr. 2016. Web. 24 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Training Requirements in OSHA Standards*. Washington, DC: Occupational Safety and Health Administration, 2015. Print.

Other Sources of Inspiration

Donald Kirkpartick, *Evaluating Training Programs: The Four Levels*, 1994

Conveyor Equipment Manufacturers Association, *Bulk Handling Conveyor Safety Video DVD*, 2010

Mine Safety and Health Administration, *Training and Retraining of Miners Engaged in Shell Dredging or Employed at Sand, Grave, Surface Stone, Surface Clay, Colloidal Phosphate, or Surface Limestone Mines*, 2016

Chapter 27

Chapter 28

CEMA Technical Report 2015-01. 26 Jan. 2015. Naples.

United States. Department of Defense. *Standard Practice for System Safety*. Washington, D.C.: Department of Defense, 2000. Print.

Chapter 29

Other Sources of Inspiration

H.W. Henrich, *Industrial Accident Prevention*, 1931

Army Material Systems Analysis Activity, *AMSAA Design for Reliability Handbook*, 2011

U.S. Department of Defense, *Military Standard: Procedures for Performing a Failure Mode, Effects and Criticality Analysis*, 1977

Chapter 30

Dalto, Jeff. JHA and JSA: The Same Thing? Different? Does It Matter? *EHS Today*. EHS Today, 9 Dec. 2014. Web. 07 June 2016.

United States. U.S. Department of Labor. Occupational Safety and Health Administration. *Job Hazard Analysis*. Washington, D.C.: Occupational Safety and Health Administration, U.S. Department of Labor, 2002. Print.

Chapter 31

Compliance with Product Safety Standards as a Defense to Product Liability Litigation. *In Compliance*. In Compliance, 1 Oct. 2010. Web. 7 June 2016.

Moore, Ron. "The Business Case for Life Cycle Cost." *Reliable Plant*. NORIA Corporation, 2016. Web. 27 June 2016.

Howard, John, M.D. *Prevention Through Design: Plan for the National Initiative*. Atlanta: Centers for Disease Control and Prevention: NIOSH, 2010. Print.

Other Sources of Inspiration

The National Institute for Occupational Safety and Health, *Preventing Deaths and Injuries While Compacting or Baling Refuse Material*, 2003

Mine Safety and Health Administration, *MSHA proposes rule to prevent crushing, pinning deaths and injuries: Rule would require proximity detection devices on coal-haulage equipment underground*, 2015

Frederic V. Hetzel, *Belt Conveyors and Belt Elevators*, 1922

Chapter 32

Other Sources of Inspiration

Conveyor Equipment Manufacturers Association, *Bulk Material Belt Conveyor Troughing and Return Idlers*, 2001

Deutsches Institut für Normung e.V., *Convinuous Conveyors – Belt Conveyors for Loose Bulk Materials – Basis for Calculation and Dimensioning, English Translation of DIN 22101: 2011-12*, 2011

Deutsches Institut für Normung e.V., *Continuous mechanical handling equipment – Idlers for belt conveyors handling loose bulk materials – Main dimensions*, 2000

Chapter 33

"American Society of Safety Engineers." *Bosc Article 6*. American Society of Safety Engineers, 2016. Web. 20 June 2016.

Carroll, Cynthia. "The CEO of Anglo American on Getting Serious About Safety." *Harvard Business Review*. Harvard Business Review, June 2012. Web. 20 June 2016.

Daniel, J. H. SME Annual Meeting. Colorado, Denver. Feb. 1991. Speech.

Estimating the Costs of Unintentional Injuries. Itasca: National Safety Council, 2012. Print.

Fabius, Raymond, R. Dixon Thayer, Doris L. Konicki, Charles M. Yarborough, Kent W. Peterson, Fikry Isaac, Ronald R. Loeppke, Barry S. Eisenberg, and Marianne Dreger. "The Link Between Workforce Health and Safety and the Health of the Bottom Line." *Journal of Occupational and Environmental Medicine* 55.9 (2013): 993-1000. Print.

Huang, Yueng-Hsiang, Tom B. Leamon, Theodore K. Courtney, Sarah D. Armond, Peter Y. Chen, and Michael F. Blair. "Financial Decision Makers' Views on Safety." *Professional Safety* Apr. 2009: 36-42. Print.

Hubbard, Douglas W. *How to Measure Anything: Finding the Value of "Intangibles" in Business*. Hoboken: John Wiley & Sons, 2007. Print.

Lazzara, Joseph. "Why Safeguarding Makes Dollars and $ense." *EHS Today*. EHS Today, 22 Aug. 2003. Web. 27 June 2016.

Morrison, Kyle W. "The ROI of Safety." *Safety and Health*. Safety and Health, 23 May 2014. Web. 20 June 2016.

"Rockwell Automation Safety Maturity Index." *Rockwell Automation*. Rockwell Automation, Inc, 2016. Web. 24 June 2016.

Safety Maturity: Three Crucial Elements of Best-in-Class Safety. Milwaukee: Rockwell Automation, 2014. Print.

Smith, Danny. "The Other Side of the Coin." *Occupational Health and Safety*. 1105 Media Inc, Apr. 2015. Web. 20 June 2016.

United States. International Social Security Association. *The Return on Prevention: Calculating the Costs and Benefits of Investments in Occupational Safety and Health in Companies*. By Dietmar Bräunig and Thomas Kohstall. Geneva: International Social Security Association, 2011. 1-7. Print.

United States. U.S. Department of Labor. *OSHA'S $aftey Pays Program*. Occupational Safety and Health Administration. 2016 Web. 27 June 2016.

Van Den Raad, W. P. Safety & The Bottom Line: Proving The Financial Benefits of Your Safety Initiatives. Indiana, Franklin. Dec. 1999. Speech.

Other Sources of Inspiration

Occupational Safety and Health Administration, *OSHA's $aftey Pays Program*, 2016

Chapter 34

"A Case for Broad Transformation." *Productivity in Mining* 2014: 1-8. Print.

"American Society of Safety Engineers." *Bosc Article 6*. American Society of Safety Engineers, 2016. Web. 20 June 2016.

Classification of Applications for Bulk Material Conveyor Belt Cleaning. Naples: Conveyor Equipment Manufacturers Association, 2014. Print.

Hubbard, Douglas W. *How to Measure Anything: Finding the Value of "Intangibles" in Business*. Hoboken: John Wiley & Sons, 2007. Print.

Morrison, Kyle W. "The ROI of Safety." *Safety and Health*. Safety and Health, 23 May 2014. Web. 20 June 2016.

United States. U.S. Department of Labor. *OSHA'S $aftey Pays Program*. Occupational Safety and Health Administration. 2016 Web. 27 June 2016.

Other Sources of Inspiration

International Labour Organization, *Introductory Report: Decent Work – Safe Work*, 2005

Ted Miller, *Variations between Countries in Values of Statistical Life*, 1999

U.S. Department of Transportation, *Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses – 2014 Adjustment*, 2014

Chapter 35

KPMG International. *Construction Procurement for the 21st Century*. KPMG International: KPMG International, 2007. Print.

United States. U.S. Department of Transportation. Office of the Secretary of Transportation. *Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses - 2014 Adjustment*. By Peter Rogoff and Kathryn Thompson. Washington, DC: U.S. Department of Transportation, 2014. Print.

INDEX

Index

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

Y

Z

AUTHORS AND ACKNOWLEDGMENTS

Authors and Acknowledgments

Authors

Andrew D. Marti

Technical Writer, Special Projects
Martin Engineering

Andrew Marti has nearly 30 years of experience in writing about problems and solutions in the handling of bulk materials.

In his three decades of service, Marti has helped Martin Engineering communicate its philosophies, products, and position as a leader in solving problems in bulk-materials handling through product literature, case histories, technical papers, publicity, conference presentations, employee training materials, advertising, and video productions.

Andy has served as author and chief editor for all four editions of Martin Engineering's *FOUNDATIONS™* books on improving belt conveyor systems through the control of fugitive material. He takes pride in helping Martin Engineering teach bulk-materials-handling industries how to improve the performance and safety of the belt conveyor systems so integral to their productivity and profitability.

Marti holds a B.A. in Journalism from Central Michigan University and an M.A. in Communications Media from the University of Northern Iowa.

A Michigan native, Marti resides in Princeton, Illinois, with his wife, Jill, and the residue of two adult children. Contact him at: andym@martin-eng.com.

Daniel Marshall

Quality Assurance Engineer, ISO 9001 Lead
Martin Engineering

A self-described 'numbers guy,' Daniel Marshall joined Martin Engineering in 2000 as a Research and Development Engineer. In that role, Marshall contributed to the design of numerous conveyor products.

After two years, he moved into a Product Engineer role. In that fourteen-year position, Marshall worked on the design and manufacture of every conveyor product offered by Martin Engineering.

In 2015, Marshall shifted into his present Quality Assurance role, ensuring that all Martin Engineering products are of the highest quality before shipment.

Marshall has had extensive experience with conveyor belt accessories and their application. In addition to his office experience, his field experience in plants across the globe allows him to speak effectively on various safety concerns in the conveyor-using industries. He has served as an author on the two most recent editions of Martin Engineering's *FOUNDATIONS™* books.

Daniel Marshall holds a Bachelor of Science in Mechanical Engineering from Northern Arizona University.

Dan lives in Neponset, Illinois, with wife, Dawn, and son, William.

Contact Dan at danielm@martin-eng.com.

R. Todd Swinderman, P.E.

Principal, RToddS™ Engineering, LLC,
Consultant, Martin Engineering

Todd Swinderman joined Martin Engineering in 1979 as a Conveyor Products Engineer and rose to become General Manager, President, and CEO. His interest has been the improvement of conveyors—and hence improving the operating company's performance—through the elimination of dust, carryback, and spillage. Swinderman's vision and leadership have focused on developing innovative solutions for bulk-materials handling and expanding Martin Engineering's presence and capabilities around the world.

After retiring from Martin Engineering in 2012, Swinderman formed RToddS™ Engineering, LLC, to provide consulting and training services around the world that helps engineers and operators design safer and more efficient conveyors.

Swinderman has been active in the Conveyors Equipment Manufacturers Association (CEMA) as an officer (including president), committee chair, and as editor and driving force behind both the sixth as well as the updated seventh edition of CEMA's *BELT CONVEYORS for BULK MATERIALS*. He is also active in the American Society of Mechanical Engineers (ASME) *B20.1* committee on conveyor safety.

In addition, Todd has been a principal author for Martin Engineering's *FOUNDATIONS™* books, including *FOUNDATIONS™, The Practical Resource for Cleaner, Safer, More Productive Dust and Material Control, Fourth Edition*, published in 2009.

He is also the developer and instructor for the *FOUNDATIONS™ Advanced Training Workshops* to improve the engineering and management of belt conveyor systems.

Swinderman holds a B.S in Mechanical Engineering (with an emphasis in Machine Design) from the University of Illinois. He maintains a Professional Engineering license in Florida and Illinois, and has been previously a licensed Professional Engineer in Idaho, Kentucky, New Hampshire, Oklahoma, and Pennsylvania.

Swinderman holds over 60 U.S. patents for improvements in the field of bulk-materials handling.*

Todd and his wife, Nancy, reside in Palm Coast, Florida. Contact him at rtodds.eng@gmail.com.

* Patents Granted:

4573567 Conveyor housing access port
4917231 Constant angle conveyor belt cleaner
6401911 Differential wear conveyor belt scraper blade
8006830 Exteriorly mounted wear liner for bulk material conveyor belt systems
4598823 Conveyor belt cleaner
6439373 Constant angle and pressure conveyor belt cleaner and tensioning arrangement
5378202 Tensioning device
7967129 Conveyor belt training idler with a locking mechanism
7367443 Conveyor belt cleaner system and method of manufacturing same
8408385 Bracket for bulk material transfer systems and method of using the same
5704167 Removable access door with multiple pivot axes
6374990 Conveyor belt cleaner scraper blade with sensor
7779987 Device for and method of sampling the amount of carryback material transferred by a bulk material belt conveyor system
6374991 Conveyor belt cleaner and tensioner assembly
5467866 Conveyor impact pillow
4643293 Conveyor belt cleaner
8028819 Constant pressure and variable cleaning angle scraper blade and method for designing same
D617521 Stringer of a belt conveyor system
7735620 Dust buildup resistant access door and door frame of a bulk material handling system
6575292 Conveyor belt cleaner and tensioner assembly
6695131 Catenary conveyor belt support apparatus
4874082 Conveyor skirt board, clamp and mounting arrangement
6457575 Self-locking pin mounting arrangement for conveyor belt cleaner scraper blades
7216756 Constant angle and pressure conveyor belt cleaner and tensioner
7424945 Conveyor belt cleaner replaceable scraper blade tip and pocket and method of manufacturing same
4944386 Scraper for conveyor belts
5048669 Modular conveyor belt sealing system
D608519 Dust cap for a support column of a bulk material belt conveyor
D543670 Scraper blade for a conveyor belt cleaner
7370750 Conveyor belt cleaner system and method of manufacturing same
D547523 Arm for a conveyor belt cleaner
7556140 Bulk material handling system
8037997 Bulk material handling system and control
7775341 Bulk material handling system
8069971 Bulk material handling system and control
5088965 Radial tensioner
7669708 Bulk material handling system and control
8205741 Method of adjusting conveyor belt scrapers and open loop control system for conveyor belt scrapers
7740127 Bulk material handling system
7740126 Bulk material handling system
5799918 Vibrator mounting arrangement
8474608 Conveyor belt guard panel blank having integrally formed handles and method of forming a conveyor belt guard panel
8267239 Conveyor belt cleaner scraper blade with sensor and control system therefor
7308980 Method for distributing a conveyor belt cleaner
7971705 Apparatus for and method of servicing conveyor belt return rollers during belt operation
4925434 Torsiconal tensioning device
8573384 Bulk material conveyor belt scraper having a dust skirt and method of using the same
4927003 Heated conveyor belt cleaner
7837030 Apparatus for and method of mounting and locking devices to conveyor belt systems
6575294 Conveyor belt skirt assembly
4898272 Conveyor belt support mechanism
4953689 Conveyor belt cleaner
9139367 Conveyor belt idler assembly
7131525 Conveyor belt cleaner scraper blade with sensor and control system therefore
7472784 Conveyor belt cleaner scraper blade with sensor and control system therefore
7866457 Conveyor belt cleaner scraper blade with sensor and control system therefore
6966430 Air supported conveyor with multi-pressure plenum system
4359150 Conveyor belt cleaner
6986418 Conveyor belt cleaner scraper blade with sensor and control system therefor
6591969 Conveyor belt cleaner scraper blade with sensor and method of manufacture

Acknowledgments

Significant Contributors

Foundations for Writing about Safety

The development of *Foundations™ For Conveyor Safety, The Global Best Practices Resource for Safer Bulk Material Handling* became a three-plus year journey that began with an idea proposed by R. Todd Swinderman, Martin Engineering's former President and CEO. That idea became a total Martin commitment; every department and every individual in the company felt the impact of the resources required to take on such a project. We made this journey because conveyor safety is often overlooked; we knew someone, or some company, had to take the lead. Martin Engineering stepped forward; we all felt that it was that important. There are always individuals who roll up their sleeves, get their hands dirty, and get the task done. Often, those individuals remain the unsung heroes who go unrecognized for the significant contributions they make to the process. Without the dedication, insight, and hard work, of Martin Engineering employees, Chelsea Blake, Paul Harrison, Jerad Heitzler, Seth Mercer, Jeff Sonnenberg, Robert Tellier, Tina Usrey, and intern, Carleen Spahn, as well as writing consultant, Mary Feeney, from Silver Oaks Communications,Inc., the publication of this book would not have been possible.

Paul Harrison

Director of Business Group – Conveyor Products
Martin Engineering

Tina Usrey

Senior Executive Administrative Assistant
Martin Engineering

Seth Mercer

Brand Champion
Martin Engineering

Chelsea Blake

Marketing Specialist
Martin Engineering

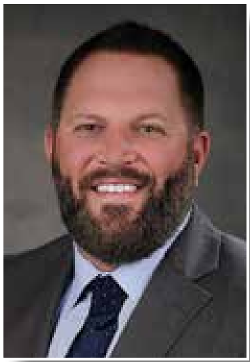
Robert Tellier

Marketing Specialist
Martin Engineering

Carleen Spahn

Marketing Intern
Martin Engineering

Core Team Members



Jerad Heitzler

Foundations Training Manager
Martin Engineering

Jeff Sonnenberg

Safety Officer
Martin Engineering

Contributing Authors

Antonio Nieto, Ph.D.

Antonio Nieto is Vice President of Global Engineering Education with the Laureate International Universities where he leads the development, growth, and academic innovation for engineering and IT academic programs within Laureate's global network.

Previously, Dr. Nieto worked at Pennsylvania State University as an associate professor of minerals engineering offering courses on earth systems, engineering economics, and computing modeling. His research focuses on mineral-extractive engineering and optimization, geo-spatial characterization, and mineral economics.

Dr. Nieto holds a BSc in Mining Engineering from Guanajuato School of Mines, an MSc in Mining Engineering from Colorado School of Mines, an MSc in Geostatistics from Ecole Des Mines de Paris, and a Ph.D. in Earth Systems Engineering from Colorado School of Mines.

Dan Brown

Dan Brown resides in New York City and is employed by Hilti North America as an Anchoring Certification Trainer. He holds a BSc in Geology from Clemson University and an MSc in Energy and Mineral Engineering from Pennsylvania State University. Additionally, he serves as a Captain in the Marine Corps Reserves. In his free time, Dan enjoys collecting rocks and minerals.

Additional Writers

Mary Feeney

Silver Oaks Communications, Inc.

Contributors

This book could also not have been completed without the assistance, and cooperation of many outside resources and many global Martin Engineering employees around the world. These individuals variously provided ideas, background information, technical expertise, photographs, writing, reviews, and support; all provided encouragement. We owe sincere gratitude to the following:

Martin Engineering Germany

Reiner Fertig, Michael Hengl, Gerard Nols, Michael Tenzer

Martin Engineering USA

Elizabeth Allen, Rick Barela, John Barickman, Rudolf Beer, Jim Bowen, Steve Brody, Nathan Carlson, Leslea Carroll, Adam Childs, Ashley Dana. Mark Daum, Jim Densberger, Michelle Ellington, Kathy Erdmann, Scott Gentry, Susan Griffith, Harry, Heath, Sonia Heath, Alan Highton, Mark Huhn, Dave Hull, Kari Kipp, Mike Komnick, Mark Luciani, Jaime Lynch, Dave McIntyre, Fred McRae, Sandy Milnes, Greg Milroy, Tammy Monier, Mike Moody, Dave Mueller, Robert Nogaj, Kathy Nyert, Timothy P. O'Harran, Jared Piacenti, Frank Polowy, Brad Pronschinske, Tracey Ramos, Raymond Robinson, Chris Schmelzer, Denise Seyller, Richard Shields, Steve Spahn, Jason Stabler, David Stahura, Mark Strebel, Gary Swearingen, Gina Taliani, Billy Tarver, Shane Tighe, Rebecca VanWaes, Nick Vargo, Janice Verbeke, Phil Wates, Barbara Wheatall, Marty Yepsen

Martin China

Jack Chen Wenjian, Eric Zheng, Jeff Zhou

Martin Engineering South Africa

Hannes Kotze

Martin Engineering India

Debjyoti Dey, Kirti Pandey, Bill Shukla

Martin Engineering Brazil

Rodrigo Trevenzolli, William Malta Valladao

Martin Engineering Mexico

Alvaro Chacon, Cesar Laredo, Javier Schmal

Martin Engineering Vibration Systems & Solutions, Michigan

Mike Lindbeck, Vice President – Engineered Vibration

Consultants

Charles E. Fleming, *FOUNDATIONS™ For Conveyor Safety,* Project Manager,
Richard P. Stahura Sr.

Silver Oaks Communications, Inc.
Grace Burt, Dan Diederich, Pat Esp, Diana Hawbaker, Anne Kirkpatrick, Danny O'Leary, Tracey Sands, Emily Snyder

Outside Resources & Others

Bruce Beck, Greg Bierie, Chris Franks, Mark Harberts, Tom Hines, Brad Neptune, Mark Stern, Terry Swearingen, Diky Trisna, Wally Watkins, James Wilson, Larry Engle

Applied Conveyor Technology
Edward Sunseri, J.R. Sunseri

Airmatic, Inc.
Rick Dougherty

Belterra
Rick Desmaris, Sergio Restagno, P. Eng.

CEMA
Phil Hannigan, Executive Secretary,
Bob Reinfried, Executive Vice President

Engineering Service & Supplies (ESS)
Chris Wilson, Terry Thew

Felcom LLC
Rick Felde

Fenner Dunlop
Geoff Normanton, Senior VP Technology

Flexco
Greg Westphall, Engineering Manager

LafargeHolcim
James Wrigley, Manufacturing Performance Support Coordinator

Luminant
Carlos Munoz

Overland Conveyor
Al Reicks

Worzalla
Rodger Beyer, Jackie Buse, Kitty Grigsby, and Production Associates.

There may be people we missed, if we did it was not intentional. If you helped but are not listed, know that we thank you for your help.

To all who stepped up, thank you.

RTS, ADM, DM, September, 2016

We would like to thank all of the customers of Martin Engineering. Their feedback, their willingness to have their sites photographed, and their cooperation was invaluable to this book.

We would also like to thank the United States Mine Rescue Association (USMRA) for the use of their extensive visual library to further explain many important concepts to our readers.

The Global Best Practices Resource for Safer Bulk Material Handling

FOUNDATIONS™ For Conveyor Safety is based on the premise that the handling of bulk materials can be done more profitably by improving the safety for those who must work on or around belt conveyors. Our mantra: **Production Done Safely™**.

With that as a goal, this volume reviews the hazards of belt conveyors and looks at design standards, regulatory requirements, and work procedures, and offers best practices for safer design, operation, and maintenance of belt conveyors.

The information contained here will assist designers and managers to understand the importance of conveyor safety and how to account for the expenses incurred with improving conveyor systems. It will also help workers and supervisors understand belt conveyor systems and how to work on and around them safely.

Visit foundationsforconveyorsafety.com
for more information and knowledge resources

ISBN: 978-0-9717121-3-3
9 780971 712133

MARTIN ENGINEERING
One Martin Place
Neponset, IL 61345-9766 USA
800-544-2947 or 309-852-2384
Fax 800-814-1553
info@martin-eng.com
www.martin-eng.com

Form No. L4049-1-9/16 WZ

Printed in the United States of America.