CEMENT INTERNATIONAL
▸ PROCESSING ▸ PERFORMANCE ▸ APPLICATION

Reprint from / Sonderdruck aus: Issue No.: 3/2013, pp. 42–49

Reducing the cost of dust collection during cement production

Kostenreduzierung bei der Entstaubung in der Zementindustrie

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Verlag Bau+Technik GmbH · P.O. Box 12 01 10 · 40601 Düsseldorf/Germany · Tel.: +49 (0) 211 / 9 24 99-0

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SUMMARY

Fugitive material has been an issue in bulk material handling for as long as conveyors have been in use. Dust and spillage create a variety of potential hazards and waste valuable resources. Consequences of regulatory violations can range from simple warnings to massive fines. A proactive approach is to eliminate the root cause, typically through the use of dust collectors to gather and filter dust-laden air. An alternative to the common central dust collector is the integrated air cleaner, which eliminates the need for large, complex air handling systems in favor of smaller, independently operating units at the dust generation points. Specifying an air cleaning system requires quantifying cost and power usage to develop a systematic evaluation of the options. In many cases, the integrated approach is superior to central designs, with lower capital investment and reduced cost of ownership.

ZUSAMMENFASSUNG

Seit es Förderanlagen gibt, sind flüchtige Stoffe ein zentrales Thema beim Umgang mit Schüttgütern. Staub und auslaufende Stoffe sind Quellen vielfältiger Gefahren, und wertvolle Ressourcen gehen verloren. Die Verletzung regulatorischer Bestimmungen kann eine schlichte Verwarnung nach sich ziehen, aber auch massive Geldstrafen zur Folge haben. Die Eliminierung der Ursachen, typischerweise durch den Einsatz eines Absaugsystems, das die staubbeladene Luft filtert, schafft hier proaktive Abhilfe. Eine Alternative zu den häufig eingesetzten zentralen Absaugsystemen bieten die integrierten Luftfilteranlagen. Anstelle großer, komplexer Systeme kommen kleinere, unabhängig arbeitende Einheiten zum Einsatz, die den Staub schon an der Quelle abfangen. Um die im Einzelfall optimale Lösung zu finden, sind sowohl eine systematische Auswertung der Optionen als auch eine Quantifizierung der Kosten sowie des Energieverbrauchs erforderlich. Vielfach erweist sich eine integrierte Luftfilteranlage mit niedrigeren Investitions- und Betriebskosten als überlegen.

(English text supplied by the author)

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1 Background

Fugitive material, most often in the form of spillage and dust, has always been a problem in the bulk solids handling industries. Ever since there have been conveyors there has been spillage (➧ Fig. 1) and dust (➧ Fig. 2), usually generated as material that falls off (or escapes from) a conveyor belt and creates a potential hazard in the surrounding environment.

Fugitive material can arise from a number of areas in cement handling systems, including dump zones, transfer points and conveyor systems. Virtually any time that material is moved, especially in large quantities or at high speeds, the potential exists to create and release dust. The situation is complicated by the fact that cement handling systems frequently have to deal with changing material conditions, making spillage control and dust management an even greater challenge.

1.1 Health and safety risks

Dust and spillage are also an on-going issue in cement handling, creating a variety of potential hazards and wasting valuable resources. In addition to the lost material, accumulated spillage from a conveyor system increases the chances for slips, trips and falls, while providing a potential source of airborne dust. It also requires clean-up, costing valuable labour time and requiring personnel to work in the proximity of a moving conveyor, introducing another possible hazard.

A serious concern for workers and local communities is the risk of exposure to crystalline silica contained in airborne dust. The term "silica" is a generic reference to the mineral compound silicon dioxide (SiO_2), which can be found in either amorphous or crystalline form. Crystalline silica is significantly more hazardous, cited as a cause of the disabling and irreversible lung condition known as silicosis, one of the oldest known occupational diseases. Any particle smaller in diameter than 10 µm has the potential to cause permanent damage to the lungs.

Under certain conditions, personal protective equipment may be required for workers who spend extended time in dusty environments (➧ Fig. 3). While this gear serves to protect on-site personnel from the hazards of inhaling airborne dust, it tends to limit visibility and slow reaction time, introducing the possibility of increased risk.

1.2 Neighbour relations and regulatory agencies

Without appropriate dust containment, cement manufacturing can be a very visible source of pollution. Airborne dust is sometimes visible miles from the offending facility, so it can draw the attention of activist groups and neighbours. Because a dust cloud is so readily apparent, complaints over dust issues can be frequent and passionate. Several facilities have been forced to alter their operations due to complaints from a nearby town.

Historically, spillage and its related issues are known only to the operation and tend to be invisible beyond the facility, except in the case of an outside inspection or safety incident. But the effects of dust releases may be felt far beyond the limits of a plant's property lines. Jurisdiction and enforcement of regulations falls to the governing agency, and authority varies by region. Consequences of violations can range from a simple warning to massive fines.

1.3 Costs

Some of the costs associated with fugitive material-related accidents can be easily identified, including medical treatment, lost wages, equipment downtime and potential legal liability. Less apparent are the costs of finding and training new employees, subsequent production delays and the supervisory time for investigating/reporting, as well as damage to equipment or tools.

If a spillage occurs then manpower and energy must be expended to control it. An operation must pay an internal worker or an outside contractor to clean the affected areas, time that could be applied to other, revenue-generating, activ-

Figure 1: Spillage

Figure 2: Dust

Figure 3: Personal protective equipment in an industrial environment

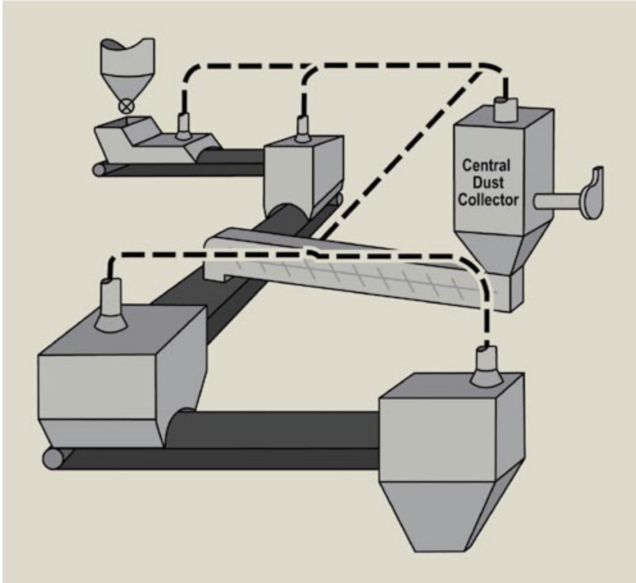

Figure 4: Central collection system

ities. In addition, if an operation is producing dust or spillage, a percentage of revenue is being lost. The dust becomes airborne and will settle out outside the material stream and remove its value. Dust also increases equipment wear, shortening the life of filters, bearings and other moving parts. Containing spillage lowers risk, reduces downtime and allows personnel to concentrate on core activities.

It's difficult to estimate the economic impact of a serious injury or death, but in 2010, the National Safety Council in the United States estimated the average cost of a work-related death to be around US$ 1.3 million, a figure that is likely to be even higher now. The accounting included medical expenses, wage and productivity losses and administrative costs, but not property damage.

1.4 Dust collection methods

A more proactive approach to these problems is to eliminate the root cause, i.e. the dust in the air generated by industrial processing associated with the movement of cement and its raw materials.

Control of airborne particles is typically accomplished in one of two ways: either preventing the dust from being created in the first place or removing particles from the air. Since dust can be created whenever materials are handled or transported, it is virtually impossible to prevent dust creation when handling materials in bulk. As a result, most efforts have focused on gathering and filtering the dust once it becomes airborne. The most common method to accomplish this is with a central dust collector, often called a baghouse.

A central dust collector consists of a single assembly containing all fans, filters and a collection hopper (❱ Fig. 4). As the name implies, this assembly is located at a central point and connected to all the individual collection points by means of sealed ductwork. This type of filtration system would handle all the dust extracted from the entire conveying system, collecting it for disposal or feeding it back into the process at a convenient point.

An alternative to the central collector is the integrated air cleaner (❱ Fig. 5), which contains a suction blower, filtering elements and a filter cleaning system. Instead of a centrally located unit connected to dust generation points via ductwork, this type of cleaner is incorporated into the dust generation point itself. The particles are not extracted, but are instead collected within the enclosure and periodically discharged back into the material stream. Unlike central systems, the integrated approach employs a series of smaller, independently operating units, one at each dust generation point.

The integrated air cleaner contains an apparatus to clean the filters using a pulse of compressed air. As material is captured by the filters, it collects on the filter media. When the filter media is pulsed, the material will fall. If it has agglomerated and the pieces are large enough they will fall back into the material stream. The pulse system is designed to alternate pulses to each filter element. When one filter is being pulsed, the adjacent filter is still drawing air. If a pulsed particle is too small to drop out of the air stream, it is immediately pulled into an active filter. This alternated pulsing eliminates the potential for a pulse to create a momentary plume of airborne dust.

2 Specifying an air cleaning system

When considering an air cleaner system for cement operations, a decision must be made between the use of a central dust collection system and an integrated air cleaner system. The cost and power usage must be quantified so that a systematic evaluation can be applied to this decision. The following model was developed to better understand and predict the costs and efficiencies of an air cleaner system.

The results presented here were calculated from several combinations of collector placements on the same application: a pair of enclosed conveyors next to a 24 m tall building (❱ Fig. 6). Each conveyor has two pick-up locations. The first is 3 m from the building and requires 28 m^3/min of air. The second pick-up point is 20 m downstream from the first and requires 56 m^3/min of air.

The series of simulations placed a central collector at four different locations. The collector application points are shown in ❱ Fig. 7 and ❱ Table 1.

Figure 5: Integrated air cleaner system

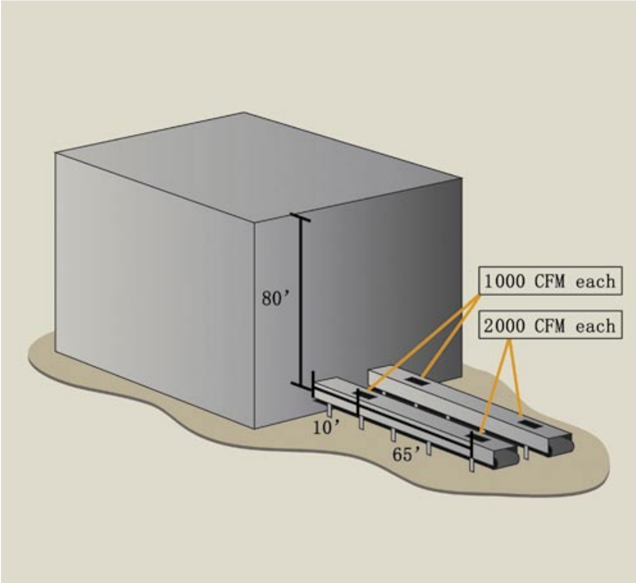

Figure 6: Dust collection application (1 000 CFM each, 28 m^3/min each; 2 000 CFM each, 56 m^3/min each)

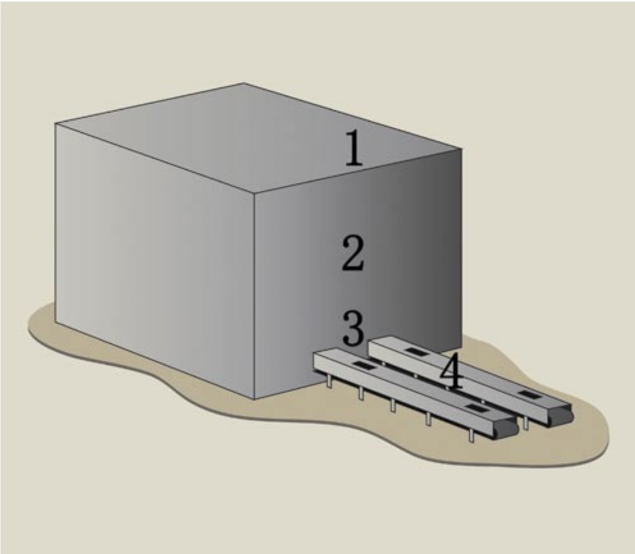

Figure 7: Central dust collector locations

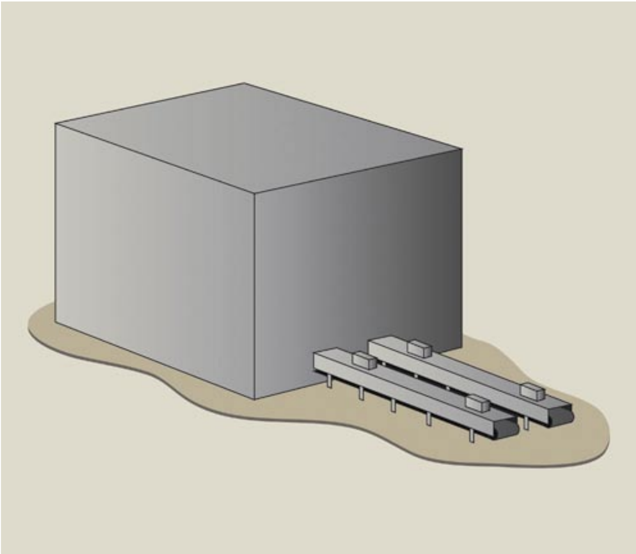

Figure 8: Integrated air cleaner locations

Situation 1 was selected as the baseline, as it is the most common arrangement in most applications. The pressure losses for each situation were calculated using a standard Donaldson duct sizing calculator. These pressure losses were used to choose a collector with adequate power.

For comparison, an integrated air cleaner (❱ Fig. 8) was also placed at each pick-up point, and the power needed to filter the required amounts of air was calculated. The costs for this system were also calculated.

All costs of power and hardware were compared, along with the advantages and disadvantages of each system.

3 Results

The next figure and table show the calculated pressures and flows for Situation 1 (collector on top of building). The system was broken into segments, as shown in ❱ Fig. 9a. The pressure loss was calculated for each section (❱ Table 2). This process was repeated for Situations 2, 3 and 4 (❱ Figs. 9b-d). The results are summarized in ❱ Table 3.

The values were used to size central dust collectors and ducting systems. Each central dust collector system requires a collector, a blower fan, a material disposal system and ducting. The collector was assumed to be a bag style collector using fabric bags as filters and an integrated hopper. The blower is backwards-inclined, capable of producing 168 m^3/min at the required pressure. The disposal system is a 9 m screw conveyor. The ducts are standard round galvanized tube sized to produce an appropriate air velocity.

The power-producing components were tabulated in ❱ Table 4. The costs for each component were tabulated in ❱ Table 5.

Table 1: Central dust collector locations

Situation	Collector locations
1	On top of building
2	20 m up building
3	At first pick-up point
4	Halfway between pick-up points

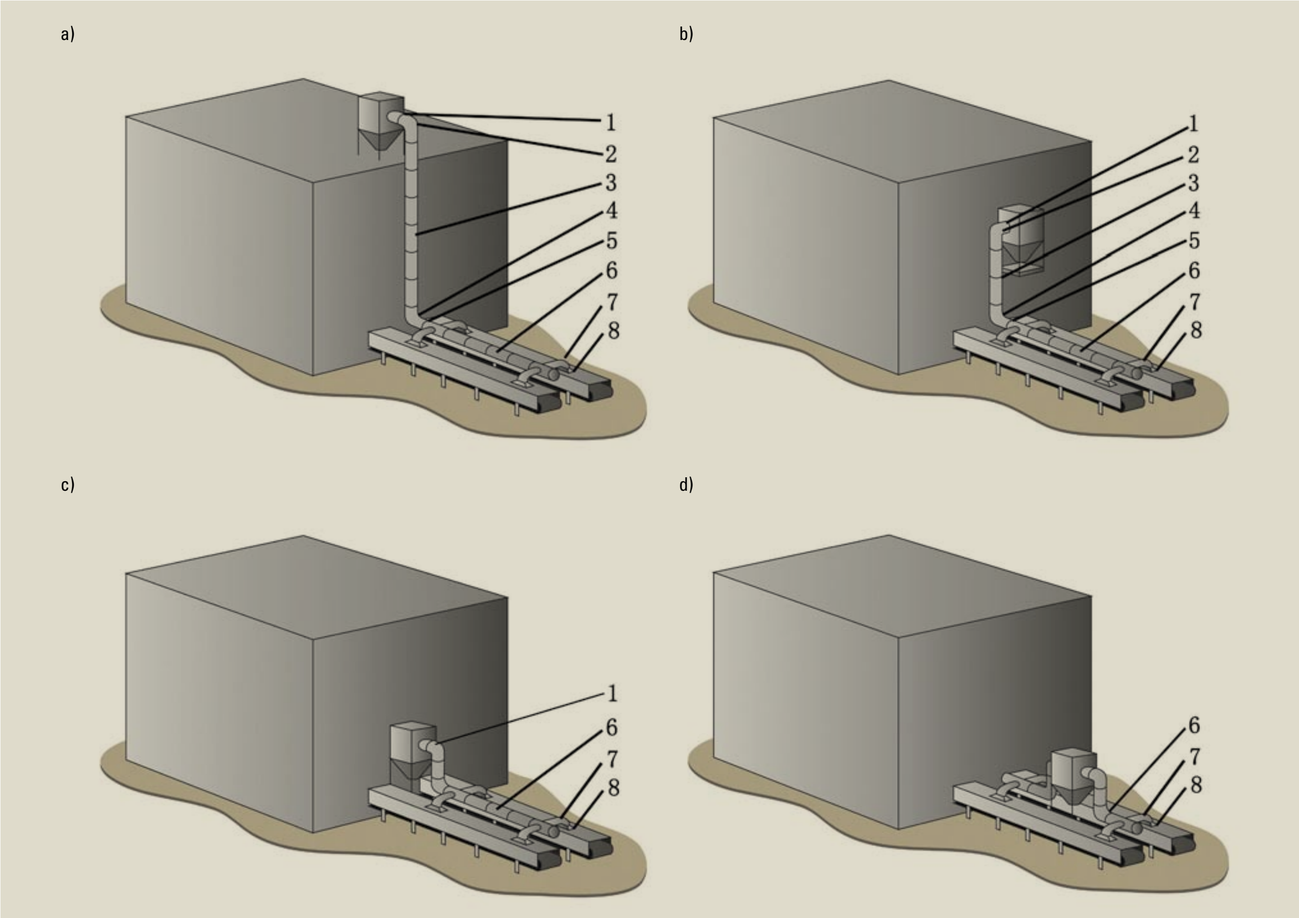

Figure 9: System segments in Situation 1 (a), Situation 2 (b), Situation 3 (c) and Situation 4 (d)

The final situation was an integrated air cleaner located at each pick-up point. The required airflow, power consumption and cost were tabulated in ❱ Table 6.

When the integrated air cleaner system is compared to the central collection system in our model, the integrated approach realizes a 24 % reduction in capital cost and a 26 % reduction in power required. In this case, the integrated system was more economical than the centralized system.

4 Discussion

The primary components of a central dust collection system are the collector, blower, disposal system and ducting. The collector is the assembly that contains the filter media bags, a system to clean these bags, a collection hopper and a rotary airlock to empty the hopper. Due to the large size and various permitting limitations, these units typically must be located outside a building. Since these collectors are sized based on the airflow, the collector is identical for each situation.

Analysis of the central collector data, combined with a thorough understanding of each component, leads to a complete evaluation of the attributes, advantages and disadvantages of a central dust collection system.

4.1 Blower

A collector uses a blower to produce negative pressure to draw air and dust into the filter media, drawing the air through and trapping dust particles within the media. The blower is sized based on a combination of the airflow required and the pressure drop the air must overcome. In addition to filter media, the blower must overcome all the pressure losses of the ducts connecting the collector and the farthest pick-up point from the collector.

The data show that the pressure losses from the ducting only account for between 49 % (Situation 1) and 33 % (Situation 4) of the total power required. The collector had to be within 9 m of the pick-up point to require a low enough pressure to allow a smaller blower.

4.2 Disposal system and ducting

Once the dust has been collected it must be re-deposited in the material stream. To accomplish this, a 9 m auger, or screw conveyor, was used. This screw conveyor used a 0.75 kW motor, so the power addition due to the disposal system was small in comparison to total power requirements.

The duct used to connect the collector to the pick-up point must be sized to prevent any dust from settling out of the air stream. This is a straightforward process, unless there are multiple pick-up points. The flow in each section of the duct must be analysed and sized so the velocity in every branch of the system is maintained. Pressure losses are proportional to velocity, so a high velocity will cause a large pressure drop.

These ducts are susceptible to dust settling out of the stream if the flow is altered, whether by workers or duct failure. This failure will not only release dust into the environment, but it will also change the balance of the system.

4.3 Central collector system details

A central dust collection system, though it is an industry standard, has several attributes that make it undesirable to

Table 2: Section pressure losses for Situation 1 (168 m^3/min collector at top of building)

Region	Note	Length [m]	Pipe diameter [mm]	Airflow [m^3/min]	Velocity pressure [VP]	Friction factor [Hf]	Loss factor	Pressure loss [mm of water]
1	Pipe out of collector	3	40	168	1.2	0.013		3.96
2	Elbow	0.3	40	168	1.2	0.27		8.23
3	Erop	24	40	168	1.2	0.013		31.70
4	Elbow	0.3	40	168	1.2	0.27		8.23
5	Out to first pick-up	3	40	168	1.2	0.013		3.96
6	Conveyor	20	33	112	1.2	0.017		33.68
7	Pipe to pick-up	0.9	23	56	1.3	0.015		1.49
8	Second Pick-up	0.3	23	56	1.3	0.026	1.7	56.13
	Filters							152.40
					Total			299.78
					Round up for safety factor			330

Table 3: Pressure loss for each situation

Situation	Notes	Total pressure loss [mm of water]
1	Collector at top of building	330
2	Collector halfway down building	330
3	Collector at pick-up point 1	280
4	Collector midway between pick-up points	250

the cement community. These include, but are not limited to: build-up of dust in the ducts, system-wide downtime when maintenance is required, high initial capital investment, high power usage, difficulty in maintaining ducts, difficulty in "balancing" airflow in ducts, and the fact that filtered dust must be recirculated or discarded, often with additional costs associated.

With a central system, individual branches of the collection system cannot be isolated, as a change in flow in one branch will impact the other parts of the system. Because of this, individual pick-up points cannot be maintained without either shutting off the system or impacting the effectiveness of other branches.

A central dust collector is a complex system with many interdependent parts so the purchase price is affected accordingly. Table 5 shows the estimated price of a central collector used in this application. Although there is a slight difference for each situation, the range is less than 7 %. Because of the almost identical losses in the duct systems, the power requirement is consistent in all situations except Situation 4, where the collector is closest to the pick-up points.

4.4 Integrated air cleaner

As with the central collection system, an integrated air cleaning system was analysed. The main components of an integrated air cleaning system are the filter housing, filter elements and the blower, which are required at each application point. The filter housing only needs to be large enough to hold the filters for the individual collection point, so it is usually small enough to fit at the pick-up location.

The integrated system does not need to be located outside, and with ductwork eliminated, a potential source of stagnant material is removed. Since the filter housing is at the application point and the filtered material is placed back into the material stream, no storage or disposal system is needed.

The integrated air cleaner contains an apparatus to clean the filters using a pulse of compressed air. As material is captured by the filters, it collects on the filter media. When the filter media is pulsed, the material will fall. If it has agglomerated and the pieces are large enough they will return to the material stream.

4.5 Blower

Like the central system, integrated units use negative pressure, with airflow created by a blower sized to provide the airflow needed for each pick-up point. There is no ducting so there are no pressure losses other than the filters that must be accounted for. Because of this, the power requirements

Table 4: Power consumption for each situation

Situation	Note	Collector power [kW]	Blower power [kW]	Disposal system power [kW]	Total power [kW]
1	Collector at top of building	0.37	14.9	0.75	16.0
2	Collector halfway down building	0.37	14.9	0.75	16.0
3	Collector at pick-up point 1	0.37	14.9	0.75	16.0
4	Collector midway between pick-up points	0.37	11.2	0.75	12.3

Table 5: Component costs for each situation

Situation	Note	Collector cost [US$]	Blower cost [US$]	Disposal system cost [US$]	Ducting cost [US$]	Total cost [US$]
1	Collector at top of building	27 000	5 500	15 213	6 428	54 141
2	Collector halfway down building	27 000	5 500	15 213	5 142	52 855
3	Collector at pick-up point 1	27 000	5 500	15 213	4 114	51 827
4	Collector at midway between pick-up points	27 000	5 000	15 213	3 291	50 504

of an integrated air cleaning system are lower than for central collection systems for the same application. Power usage is a major factor in the lifetime cost of ownership.

4.6 Integrated Collector System Details

Because the integrated air cleaning system utilizes a series of independently operating assemblies at each dust generation point, the loss of a single unit to maintenance will not result in an operation-wide shutdown of the dust collection system. This decentralized arrangement allows cleaners to be put into a maintenance cycle, so each unit can be maintained at times other than during a full system outage.

The nature of the integrated air cleaner design eliminates many of the disadvantages of a central dust collector, while providing the same level of filtration. With no ductwork, there is no chance of dust build-up, no balancing and no duct maintenance. The individual components will operate only when needed, helping to reduce energy requirements. Because it can return the dust to the process, there is no need for a separate dust disposal system.

5 Conclusion

Spillage has always been a recurring issue in the bulk material handling industries. Dust has been present as long as spillage, but the consequences of dust have recently received increased prominence. The consequences of dust

Table 6: Integrated air cleaner data

Pick-up point	Airflow [m^3/min]	Power required [kW]	Cost [US$]
1	28	2.2	8500
2	28	2.2	8500
3	56	3.7	12000
4	56	3.7	12000
	Total	11.8	41000

include health and safety risks, strained neighbour relationships, increased regulatory pressures, and the loss of productivity of those needing to clean it up.

The industry standard for removing dust from the air is the central collection system, or baghouse. An alternate method of removing dust from the air has been developed in the form of an integrated air cleaning system.

The options must be compared carefully before selecting a dust control solution. Consideration must be given to power usage, cost, and advantages or disadvantages of each option. In the case shown above, an integrated air cleaning system is superior to a central dust collection system in the areas of power usage and cost of ownership, initial capital investment, and in comparison of advantages and disadvantages. In this example, the integrated approach realizes a 24 % reduction in capital cost and a 26 % reduction in power required over the central system.