Series on Dust Control

By: R. Todd Swinderman

This series of articles focuses on the practical methods of dust control in bulk material handling by conveyor belt. Much emphasis has been placed on respirable silica dust but, current research indicates that while some materials like the “Big Three” silica, asbestos, and coal dusts are well known to cause debilitating diseases, industry should not discount the health and productivity concerns associated with prolonged exposure to dust from virtually any bulk material. The engineering and administrative technique(s) used to control the “Big Three” can be applied to mitigate almost any dust problem. The series starts with a background on silica dust control because many of the ventilation and respiration techniques have their origins in silica dust control. Section two discusses controlling dust generation at the source and sections three and four deal with dust settling and extraction engineering controls and techniques.

Engineering controls are the preferred method of dust control by regulatory agencies.[1] The initial price for engineering controls can be higher but the safety, operating, and process costs can be lower over the life of the conveyor. Engineering controls should be the first line of defense whenever feasible as they provide the highest level of protection for the worker and usually operate independently of worker decisions and actions on the job.[2]

Section 1 - Background

Like many hazards in the bulk material handling industry dust is not precisely defined but can be found everywhere. Exposure to dust of any kind has been directly linked to numerous diseases and chronic conditions due to the lungs and upper respiratory system’s reaction to inhaling certain dust. There are an almost incomprehensible number of acronyms, units, and calculation methods used in the study and control of dust. The most common unit used for dust concentrations is milligrams (1/1000th of a gram) per cubic meter (mg/m^3), micrograms (1/1,000,000th of a gram) per cubic meter (mg/m^3), and microns (m) (1/1,000,000th of a meter) for particle diameter.[ed]

Recognition of the Dust Hazard

For a long time, inert inorganic or organic dust with less than 1% silica was thought to have no long-term permanent health effects possibly because there was no link to the diseases caused by the widely studied silica and asbestos dust.[1] Reactions to nuisance dust were considered temporary and reversible but recent research indicates that prolonged exposure contributes to chronic diseases such as dermatitis, asthma, and chronic obstructive pulmonary disease (COPD) among many others.

Dust of 10 µ and below are considered respirable with a potential for particles being retained in the lungs and causing serious diseases such as asbestosis from asbestos, silicosis from silica, and coal workers' pneumoconiosis caused by coal dust. Other minerals such as aluminum, antimony, barium, graphite, iron, kaolin, mica, and talc are known to cause lung disease. Dust is not just a disease hazard as certain dust presents explosion risks under the right combination of concentration, enclosed space, and an ignition source. The National Institute of Occupational Health and Safety (NIOSH) generally considers combustible dust to be particles of 500 microns or smaller of finely divided solids.[2]

Nuisance dust can be any size but is generally visible particles of 40 microns and larger than we notice. The US Occupational Safety and Health Administration (OSHA), in CFR29 1910.1000 table Z-3, lists PEL guidelines of 5 mg/m^3 for respirable and 15 mg/m^3 total concentration for insoluble or poorly soluble particles not otherwise regulated (PNOR) that do not have established exposure limits (nuisance dust). The US Mine Safety and Health Administration (MSHA) in CFR 30 Sections 56.5001 and 57.5001 refers to the threshold limit values published in the 1973 edition of the ACGIH publication, Industrial Ventilation

Besides the obvious creating housekeeping issues and reduced visibility challenges, nuisance dust can contribute to corrosion and is a significant contributor to bearing failures.

From a health standpoint, only certain known materials in dust form are considered hazardous enough to require classification and control, but all dust presents respiratory, vision, and skin condition hazards that affect worker productivity and employer costs and therefore production and profits. These effects and costs can be quantified as described in detail in Foundations™ for Conveyor Safety, available for free download from www.martin-eng.com.[3][i]

History of Silica Dust Control

The link between mining and respiratory disease has been suspected since Hippocrates observed miners wearing face coverings to protect themselves from fatal dust. By the 17th century, a direct connection between disease and stone cutting was identified. In the 19th century, silica dust was identified as the cause but little was done to protect workers. The West Virginia Hawks Nest Tunnel disaster in 1936 created a huge public outcry and greatly increased public awareness of the dangers of silica. Approximately 764 miners died in a relatively short time and eventually up to 1,500 died digging a water supply tunnel through rock containing large percentages of silica.[4][i] The Hawks Nest disaster triggered congress to set a limit on government contracts but not on the mining industry as a whole. Because so many workers were potentially exposed and because many lawsuits were being filed, affected industries formed The Air Hygiene Foundation to set the "practical" limits (limits that would not reduce production) for dust exposure and to limit their liability. Their initial recommendation for silica dust levels was 5 mppc or about 500 mg/m^3.

Engineer Controls

State of New York Public Health Department was one of the first to set standards for exposure and methods of control in 1942. The first standards were based on the average of the particle counts per cubic foot during a 10-minute exposure. The method used to determine the concentration was to illuminate the sample and under a microscope, count the number of particles and relate it to the volume of air without providing a particle size distribution. [5][i]

Class of Stone	Free Silicon Dioxide Content of Stone	Maximum Allowable Atmospheric Dust Concentration
I	Any stone formation having free silicon dioxide as a component part and containing uniformly less than ten (10) percent by weight of free silicon dioxide.	100,000,000 particles per cubic foot of air (mppcf) (= 10 mg/m^3 ~ 10,000 mg/m^3)[ed]
II	Any stone formation having free silicon dioxide as a component part and containing ten (10) percent or more by weight of free silicon dioxide.	10,000,000 particles per cubic foot of air (mppcf) (= 1 mg/m^3 ~ 1000 mg/m^3)[ed]

One of the first Exposure Limit Regulations for Dust Containing Silica

Equipment	Recommended Exhaust Design Values
Crushing & Grinding	200 fpm
Flat Screens	50 cfm/sf of screen deck @ 200 fpm
Loading Hoppers	100 cfm/sf of open area
Conveyors	350 cfm/ft of belt width @ 200 fpm

Recommended Rate of Air Flow Through Hoods and Enclosures[6]

The recommended control methods were:

1) Local exhaust ventilation

2) Wet method of control

3) General ventilation shall not be employed as a control means except where:

a) The weight of free silicone dioxide in the stone is less than 10% by weight or;

b) Where the worker is not constantly exposed or;

c) the operations are done in open air.

4) Respirators as a secondary means when other means do not provide adequate control

5) Any other method, or methods, approved by the Board of Standards and Appeals

These ventilation guidelines are very similar to what most conveyor designers still use today based on the guide, Industrial Ventilation.

Permitted Exposure Levels

Research improved the understanding of silicosis and dust measurement methods. Gradually, exposure limits were able to be determined based on medical science with the understanding that it is the smaller particles that pose the greatest health risks for the silica content. The exposure limit remained at 5 million particles per cubic foot until OSHA issued its first silica standard, setting the exposure limits based on the density of silica particles in the air over an eight-hour period. In the construction industry and in shipyards, a worker could not be exposed to more than 250 micrograms per cubic meter over an 8-hour period. In all other industries, a worker could not be exposed to 100 micrograms per cubic meter. The 100 micrograms per cubic meter remained the threshold until 2016 when OSHA issued and The US Mine Safety and Health Administration (MSHA) followed with a final rule requiring the protection of workers from respirable crystalline silica exposures above the permissible exposure limit (PEL) of 50 µg/m3, averaged over an 8-hour day;[7] The key provisions of the current OSHA regulations are the following:

- Reduction in the PEL for respirable crystalline silica to 50 µg/m3, averaged over an 8-hour shift
- The use of engineering controls to limit worker exposure to the PEL
- Providing respirators when engineering controls cannot adequately limit exposure
- Limiting access to high-exposure areas
- Offering medical exams to workers exposed above the action level of 25 µg/m3
- Training workers on silica risks and how to limit their exposures

Interestingly, the recommended control measures remain much the same as in 1941 with ventilated enclosures being the preferred method with a strong emphasis on housekeeping and cleanup methods that do not re-entrain the dust into the air.

Conclusion

Usually, diseases progress slowly and workers are often put on disability long before they die so the horror of an accidental death at work without warning is not much of a motivator for corrective action. It has been known for a long time that some dust creates significant health hazards and despite political wrangling, some positive developments are taking place such as the reduction of the silica exposure limits. The control of dust in the workplace is getting much more regulatory scrutiny and clearly, the trend is toward tighter exposure limits for all dust. The OSHA Pays Calculator[8] estimates the direct and indirect costs of uncontrolled dust at over $73,000. For controlled dust (dust with an exposure limit), the estimate is $388,000 per incident. Clearly, a financial and moral justification for dust control can be made.

References

[i] OSHA Technical Manual (OTM) Section 5: Chapter 3, https://www.osha.gov/otm/section-5-construction-operations/chapter-3

[ii] NIOSH's Hierarchy of Controls Health & Safety Training, NES Safety Topic - April 11, 2019, OSHA Fact Sheet OSHA3682

[iii] Public Health Then and Now, The Limits of Thresholds: Silica and the Politics of Science, 1935 to 1990 Gerald Markowitz, PhD, and David Rosnet; PAiD, MPH February 1995, Vol.85, No.2 American Journal of Public Health

[iv] https://www.osha.gov/laws-regs/standardinterpretations/2013-12-27

[v] Industrial Ventilation, A manual of Recommended Practices, 29th edition, American Conference of Governmental Industrial Hygienists

[vi] Foundations for Conveyor Safety, Martin Engineering, 2016 https://foundations.martin-eng.com/book-form-download-page

[vii] NIOSH [2019]. Dust Control Handbook for Industrial Minerals Mining and Processing. Second edition. DHHS (NIOSH) Publication No. 2019–124, RI 9701. https://doi.org/10.26616/NIOSHPUB2019124

[viii] Rules related to the control of silica dust in stone crushing operations, State of New York, Department of Labor Board of Standards and Appeals section 34-4, Effective July 1, 1942

[ix] www.osha.gov/sites/default/files/publications/OSHA3682.pdf

[.ed] Editor's Notes:

OSHA uses the conversion factor of .1 mg/m^3 = 1 mppcf based on the density of silica.

1 milligram (mg) equals one-thousandth of a gram
1 microgram (mg) is one-thousandth of a milligram or one-millionth of a gram (g)
1 microgram per cubic meter (1 mg/m^3) equals one-millionth of a gram or one-billionth of a kilogram per cubic meter (m)

Section II – Reducing Dust at the Source

While obvious that one way to reduce dust emissions is to reduce the amount of dust created in processing, it isn't always practical or easy to accomplish. There are many dust sources that have to be managed depending on the extraction, haulage, and storage methods. Most of the dust contained in bulk materials is from crushing or grinding to reduce particle size and from transfers from one step in the production process to another such as at conveyor transfer points or discharge onto a stockpile.

Surface Operations

In surface operations, control of dust at the extraction point is difficult because it happens in the open air and the fracturing of the in situ material creates dust. Typically, the bulk material is loaded into haul trucks at the point of extraction and taken either to a conveyor transfer point or a crusher. As the material is dumped and crushed, the most effective dust control is the use of water or if water addition to the material is a problem, foam is used. Water isn't as effective as foam but is often preferred due to the cost of foaming chemicals. There are some residual effects of water but they are usually short-lived. In underground extraction, water is often used at the face and conveyor transfer points to control dust. When water cannot be used, such as in mining salts, ventilation and modular dust collection are options.

Conveyors

Conveyors are a major source of dust emissions but they can also aid in reducing fugitive dust. For example, in pit crushing and overland conveying, there is reduced total site dust generation compared to truck haulage. Some materials are easily degraded by handling or degrade over time in storage. A dust control strategy for these types of materials would include minimizing handling and dead time in storage. Bulk materials that are easily windswept may require an enclosed system or the application of a closed conveyor belt system such as a fold belt, pipe conveyor, or air-supported conveyor.

When the haulage involves a conveyor belt, dust generation is a function of the loading and discharge as well as how it is managed. Closed conveyors are very useful for preventing contamination and protecting the cargo from the elements, but they still have to be opened and closed for loading and discharge. Passive dust reduction strategies include lower belt speeds, minimum belt sag, shorter drop heights, fully enclosed transfers, and managing the flow to minimize impact and induced air.

There are many suggestions for belt speeds based on the properties of the bulk material. ANSI/CEMA 550-2003 Classification and Definitions of Bulk Materials lists miscellaneous properties of bulk materials that would contribute to a decision to use a lower belt speed: B-1 Aeration-Fluidity, B-6 Degradable-Size Breakdown, B-8 Dusty, B-20 Very Light and Fluffy - May be windswept as part of its classification code system. With lower belt speeds, the belt width has to increase to convey the same tons per hour creating a capital cost vs operating cost dilemma. Many sources suggest belt speeds of 2 m/s or less for reducing dust generation. If a conveyor is being designed for an extended lifetime then it is worth the effort to closely compare the capital savings from a higher-speed belt to the long-term costs of maintenance, cleanup, and safety. There are clear relationships between increased cleanliness, fewer safety incidents, and more reliable production so the tradeoffs should be examined closely. Foundations™ for Conveyor Safety provides a detailed methodology and data sources for including direct and indirect costs in the financial analysis in section six.

Storage

Controlling dust at the storage location is another challenge. Large stockpiles are impractical to enclose in buildings and are often stacked out and reclaimed by machinery that generates additional fines. Open stockpiles are subject to the weather where some bulk materials degrade upon exposure to the atmosphere and some materials will revert to a solid state when exposed to humidity or rain. Those materials that can be wetted often use water sprays to reduce windblown dust. Other strategies include wind fences and compacting the pile.

Discharge onto the pile is a source of dust release as the material flows from the delivery equipment, often a conveyor, onto the pile. Cascading or telescoping chutes can be used to reduce the release of dust in these cases. If the material is easily broken, the drop height from discharge to the pile or between cascade shelves can create additional dust from impact degradation. One unexpected source of dust emissions can be the site layout. For example, if a slope conveyor going from the stockpile into a storage bin or building is orientated in line with the prevailing winds in a high wind locale, the wind flowing up the conveyor will overwhelm dust control strategies by creating positive pressure throughout the conveyor enclosures.

Often overlooked in a dust reduction strategy are design choices that can minimize dust creation from the undulations of the bulk material on the belt as it is transported. Managing belt tension so the sag between idlers is minimized reduces the effects of material trampling and splash. Material trampling is the particle-to-particle movement created by the change in the bulk material profile as it goes over the idlers. Trampling and splash can be a source of dust generation given a large number of times the cargo passes over idlers every hour. The higher the belt tension, the lower the trampling loss. Similarly, at a critical speed, the bulk material loses contact with the belt at the idler and is launched into the air, falling back onto the belt at a slightly lower speed than the belt. This splashing action opens the profile, creating induced air flows that can release dust, creating turbulence, impact, and degradation as the material lands and returns back up to belt speed. Keeping the belt sag to 1% between idlers is a frequent specification. Usually, the concerns in conveyor design from these belt sag phenomena are the added belt tensions required to overcome the frictional losses.

Material Drop Height

Drop height between discharging and receiving equipment is another criterion to consider in a dust control strategy. There may be layout or physical constraints that dictate the drop height. For example, discharging into a bin or silo when it is empty vs partially full or restrictions on overall building height may require as short as possible drop heights. One often overlooked in establishing the drop height is the need for installation and maintenance access to belt cleaning equipment. Generally, a drop height of two meters or more will provide adequate space for these tasks and provide the opportunity to keep the material flow in a more defined stream and load it on the receiving belt gently. If the dropping material is not controlled but allowed to fan out or bounce off chute walls, the amount of induced air into the transfer point is greater than necessary and the impacts can create additional particle attrition. If cascade chutes are used on lighter material, it can be useful to understand the terminal velocities of the particles and set the distance between cascades close to when the material reaches terminal velocity. Research has shown that more frequent transfers with shorter drop heights can reduce dust emissions.[i,ii]

Material Stream

If the material stream can be constrained so that it does not open up when discharged, the amount of air induced into the transfer point is reduced. As the material particles spread out, it creates a low-pressure area in the spaces which induces airflow into the transfer point. The amount of dust that can become airborne is directly proportional to the volume and speed of the airflow through the transfer point. If the openings in the chute work are restricted to the practical minimum, the inward airflow is restricted. A useful dust control strategy is to capture the material shortly after discharge and keep the stream coalesced as tightly as possible to reduce induced air. There are a number of Discrete Element Modeling (DEM) software programs specifically designed for the design of material flow through chutes and there are specialty chute manufacturers that specialize in these techniques. These chutes work best with materials of consistent size and adhesive and cohesive properties. Wear on the chute surfaces may be accelerated but this can be offset with a maintenance-friendly design for quick and easy change out of wear surfaces.

Conclusion

Much emphasis is placed on planning the mine or process plant to maximize profitability but little attention is placed during the initial feasibility studies on how the layout can affect dust creation and emissions. Conveyor transfer points have a history of being drafted rather than designed. Design tools are now readily available to address these critical details. How the conveyor is operated and maintained also has a significant effect on dust generation and release.

References

i NIOSH [2019]. Dust Control Handbook for Industrial Minerals Mining and Processing. Second edition. DHHS (NIOSH) Publication No. 2019–124, RI 9701. https://doi.org/10.26616/NIOSHPUB2019124

i[i] Powder Technology 176 (2007) 77–87 Review, Degradation characteristics of steel making materials during handling, R. Sahoo*

Section III - Passive Dust Control Enclosures

The mathematics of the flow of heterogeneous mixtures such as dust and air is quite complex and difficult to study using physical models. As a result, many of the equations and diagrams used in this section on passive dust control are simplified to be of more practical use. Only recently are researchers focusing on using advanced Discrete Element Modeling (DEM) and Computational Fluid Dynamics (CFD) programs to study how to reduce dust emissions in conveyor transfers.

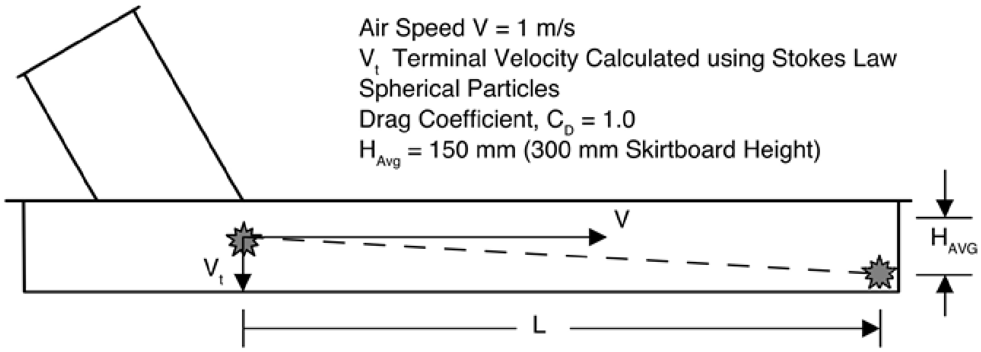
Passive dust control uses enclosures to reduce the total emissions without external energy input. The enclosures discussed in this section are the discharge chute, the receiving chute, and the skirtboard extensions on a typical troughed conveyor belt handling bulk materials. Passive dust control also reduces spillage and leakage because effective passive dust control requires sealed chute designs, including the entrance and exit of the bulk material from the transfer system and the sealing of the skirtboard to the belt extension. Other methods, such as windscreens or conveyors totally encapsulated within an enclosure. Treatment of the transfer design when accessories such as samplers or magnets are present is not discussed but many of the concepts covered will still apply.

Safety

Safety incident statistics related to cleaning and reactive maintenance account for as much as 50% of all conveyor-related injuries.[I] Fugitive materials from bulk material handling include dust, spillage, leakage, and fumes. The control of fugitive materials has been said to reduce maintenance requirements by as much as 85%.[ii] Release of nuisance dust particles, 40m < 100m, can be virtually eliminated, and respirable dust release can be minimized with a well-designed and maintained passive dust control system. Controlling fugitive materials will reduce the frequency of cleaning and transfer point maintenance, allowing production to continue on schedule while reducing the frequency of worker exposure to hazards.

Enclosure Design

A conveyor transfer is both a dust generator and a dust-settling chamber. Classical settling chamber designs suggest that skirtboard extensions are seldom long enough to allow the particles to settle with the given airspeed and particle size. A basic estimate shows that for the particles of most concern for health (1 to 10m), the skirtboard lengths would be unrealistic for gravity settling alone.



Solid Density kg/m³	Settling Distance L (m) vs Particle Size & Density			
	1 µm	10 µm	50 µm	100 µm
500	9900	99.0	4.0	1.0
1000	4950	49.5	2.0	0.5
2000	2500	25.0	1.0	0.3
3000	1650	16.5	0.7	0.2
4000	1240	12.4	0.5	0.1

Typical Specific Gravities Spgr. x 1000 kg/m³ = Solid Density	
Wood	0.5
Coal	0.7
Limestone	2.7
Lead Ore	3.4
Iron Ore	4.0

Settling Distances for Various Particle Diameters and Densities

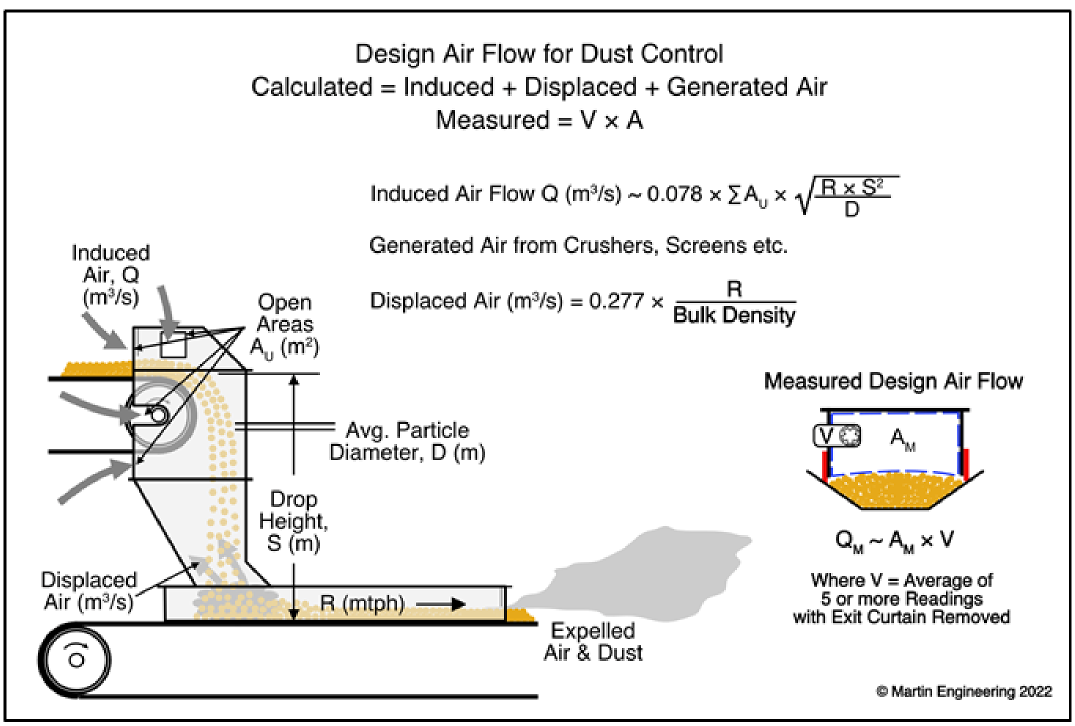
Particles >50 µm do not usually remain airborne very long as they have a terminal velocity of >7cm/sec. The terminal velocity of a 1 µm particle is about 0.03 mm/sec, so movement with the air is more important than sedimentation through it.[iii] As a result, many manufacturers and designers try to create recirculation of the dust particles within the transfer point to allow the dust to agglomerate or collect on flexible curtains where it will eventually fall onto the belt as a larger and heavier mass.

Conveyor transfer point performance suffers from empirically derived design rules and accessory designs. There are hundreds of small and large companies manufacturing and promoting accessories to treat dust emissions. There are numerous and often contradicting design rules that are prevalent in the industry with little or no scientific basis. These rules often originate from the treatment of symptoms without an engineering understanding of how and why they improved the situation. These design rules often vary by the industry even though the basic conveyor is the same. The fixes may work in one situation but not in another and rarely treat the root cause of the problem. The same is true of problem-solving accessories. Regardless, these rules often become standard practice and are seen written into specifications.

With passive control systems, there is a much greater need to 'understand the system' before an appropriate passive solution can be implemented.[iv] The knowledge of the system includes; the bulk material properties, the drop height between transfers, the tonnage and how it varies over time, the operating schedule, the belt width and speed, the existing chute geometry, and the physical space and access available for modifications.

The particle size distribution is an important factor in estimating the amount of air that is generated by the discharge and receiving of the bulk material. The quantity of dust in the bulk material is normally not a major consideration in passive control, it is the turbulent air caused by the discharge of the stream of material and the impact with the receiving conveyor that are the main concerns in designing passive dust control. With a conventional chute, the material spreads out as it falls through the chute while air flows into the spaces created and the dust that is mixed in the material becomes airborne. This air is called induced air. There are a number of formulas for calculating the induced air and many researchers have modified the formulas to try to improve the accuracy of the calculation. An alternative for existing transfers is to safely measure the average air speed at the exit of the skirtboards while the conveyor is operating at full capacity. With the average velocity and the cross-sectional area of the exit, the total volume of airflow through the transfer can be easily estimated.

Displaced air is the volume of air in the enclosure that is displaced by the initial stream of material flowing into the transfer point on start-up. Often, there is a quantity of material and settled dust on the receiving belt from the last shutdown. The impact of the stream of bulk material is what creates the initial puff of dusty air that can often be observed bellowing from the transfer point on start-up. This volume of air must be included in the calculation of the total air to be conditioned. Generated air comes from accessories or process equipment connected to the transfer point or skirtboard enclosures. Common sources are rotary crushers and screens. Some manufacturers will have data on how much air these devices can generate and it can be significant in the range of 0.25 to 0.75 m3/s.v When this volume flow is added to the induced air, displaced air may be more than what can be treated passively.

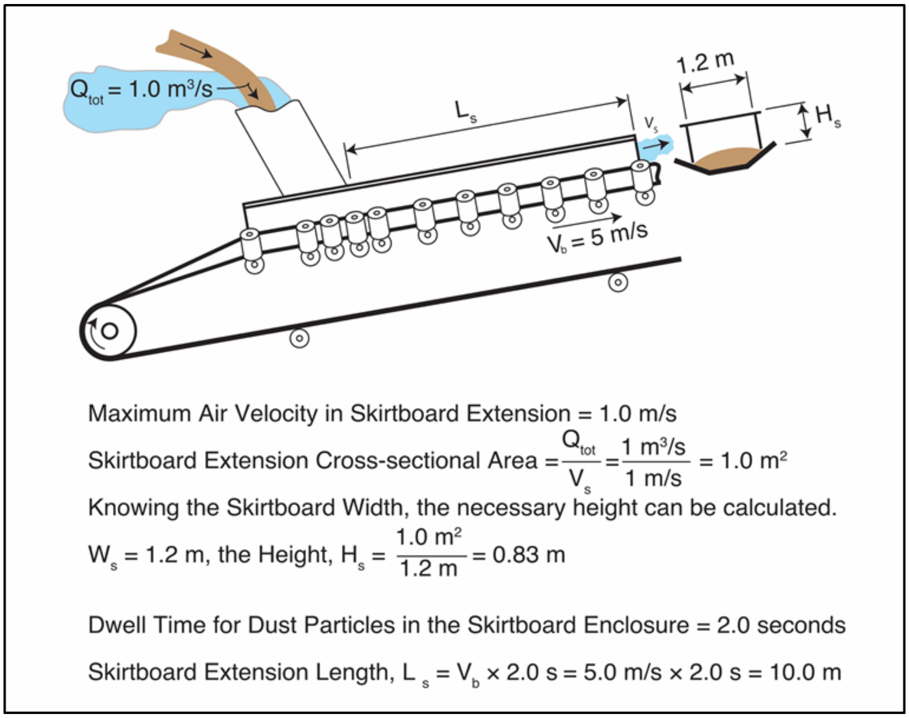


Calculating or Measuring the Amount of Air to be Passively Controlled

The separation of the discharged particles generates a vacuum in the spaces, created as the particles fall and pulling air into the enclosure. The smaller the openings, the more resistance to inward flow and the less air induced. It is evident from the induced air formula that there are certain variables that can be somewhat controlled to reduce induced airflow. The most obvious and easiest to modify is the amount of open area in the system. Details as simple as keeping covers on the skirtboard extension and inspection doors closed and maintaining dust curtains at the entrance to the discharge chute are important. Other openings that are often ignored such as belt cleaner service openings and the spaces between the top and bottom runs of the belt where it enters and leaves the head chute and shaft openings also need to be sealed as much as practical.

The other variables, drop height and particle diameter are difficult to change on existing installations, but research has shown that larger particle sizes and reduced drop heights are effective in helping control hazardous dust. The particle diameter is usually not easy to change but on new designs cascading conveyors to reduce drop heights is an option that should be considered to reduce particle size degradation and dust generation.[vi]

Settling chamber design has classically involved reducing the velocity in the chamber and using baffles to prevent turbulent flow. Air speeds in settling chambers are typically 0.3 m/s for ≤ 10 m to 3.0 m/s for ≥ 50 m.[vii] Several sources including one of the first regulations on silica dust, the State of New York and the ACGIH Industrial Ventilation Manual state that airflow into conveyor enclosure openings should be 0.75 to 1.0 m/s. There are numerous empirical formulas for the length of the skirtboard extension based on belt width or belt speed ranging from two times the belt width to 1.2 m per 1.0 m/s of belt speed. There is a formula for the length of a receiving conveyor that is needed for the bulk material to settle into a stable profile within the enclosure after loading. The two most commonly applied empirical rules are to keep the air velocity below 1.0 m/s and to retain the dust in the skirtboard extension for at least 2 seconds.

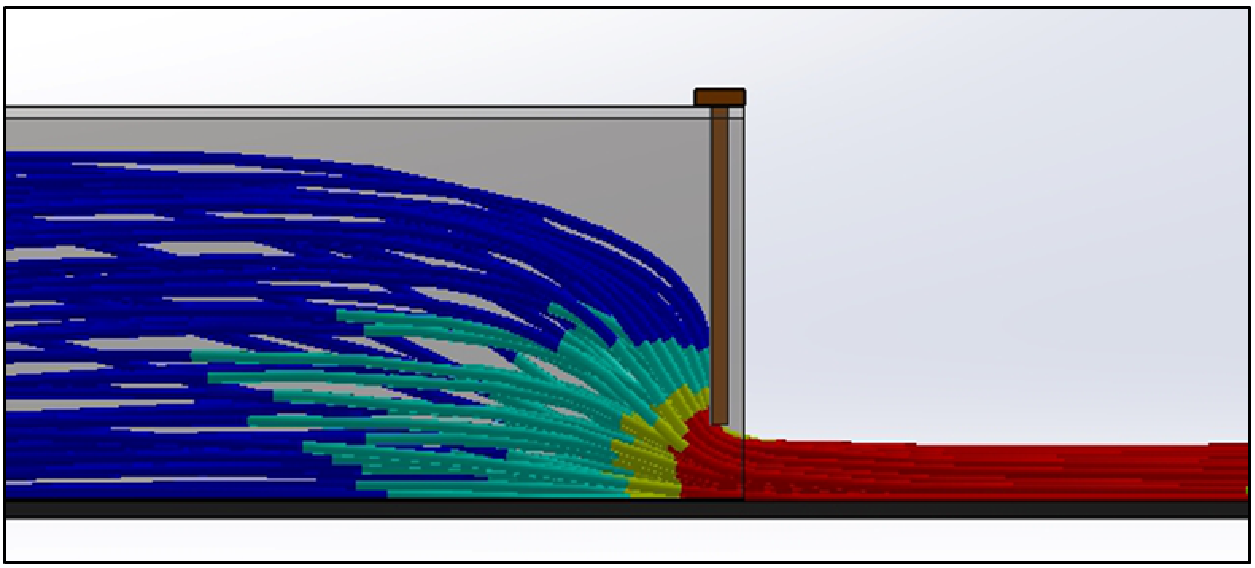


Basic Skirtboard Extension Calculation Example

The example results in a skirtboard extension 1.2 m wide, 0.83 m high, and 10.0 m long. For the criteria given, the 10-meter length doesn't seem unreasonable but the 0.83 m height may be something that seems unusual. Most skirtboards aren't sized for dust control but for keeping fabrication costs down so a 300 mm skirtboard height is common because it accommodates an adequate height for wear liners and the installation of most sealing systems. In comparison, a rough estimate for a settling chamber would be of similar height and width but the length would need to be 12.4 to 99 meters depending on the particle density. Field observations confirm that the 1 m/s airspeed and the 2-second dwell time result in an enclosure that adequately controls visible dust. It is believed the addition of multiple dust curtains inside the enclosure encourages recirculation of the air and allows smaller dust particles to agglomerate and fall out as quickly as the larger particles do in a matter of a few meters. However, CFD and DEM analysis shows that setting up the recirculation is not done with a random number of curtains spaced wherever convenient.

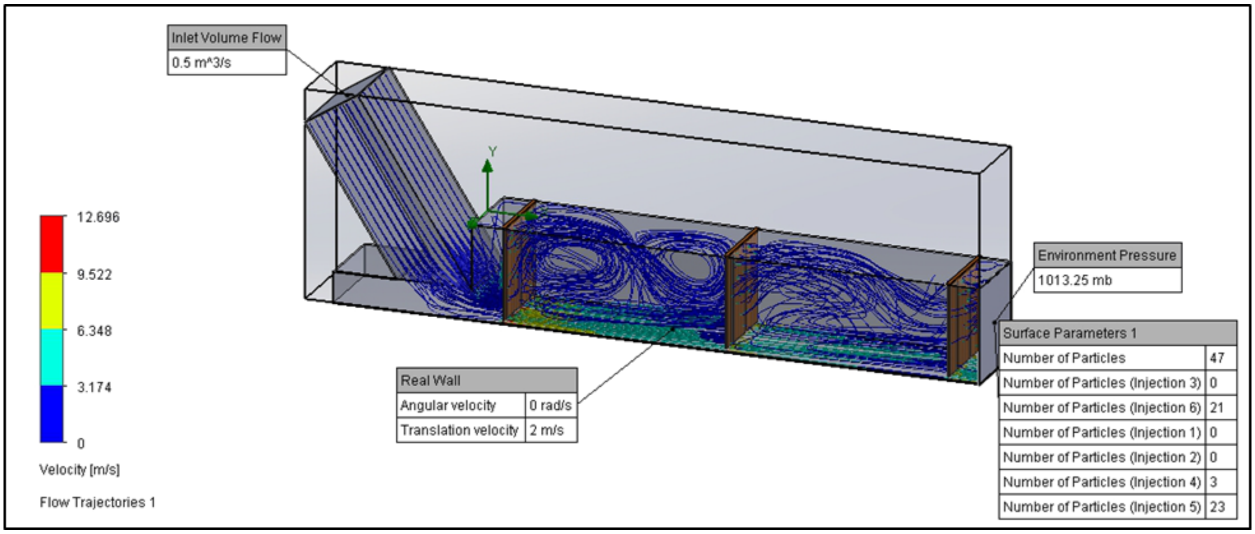
A study on an iron ore dump station showed that setting up the recirculation requires a certain internal baffle design at the entrance to the skirtboards. The theoretical results were verified with scale laboratory tests.[viii] Another CFD analysis of transfer from one belt to another suggests that placement and maintenance of the dust curtains are critical to reducing dust emissions.[ix] The height and the length of the enclosure extension of 0.6 mm and 3.6 m were found to be economical as taller and longer enclosures offered little additional dust settling. In this research, air flows of up to 0.25 to 0.75 m3/s, belt widths between 1,000 to 1,800 mm, and belt speeds up to 8.0 m/s were used as inputs. Numerous enclosure geometries and dust curtain arrangements were modeled with dust particles from 1 to 100 m of varying densities. The model predicts that nuisance dust ≥ 40 m were completely settled out and respirable dust could be reduced by as much as 85%.

An unexpected result of the CFD study was the design of the dust curtains. It was found that the conventional rubber curtain razor slit to have 50 mm wide fingers actually increased dust emissions because it caused the air to speed up to go under the curtains. If conventional internal curtains were used there was practically no recirculation because the airflow had to pass under the gap between the curtain and the material, speeding up the velocity and keeping dust particles suspended.



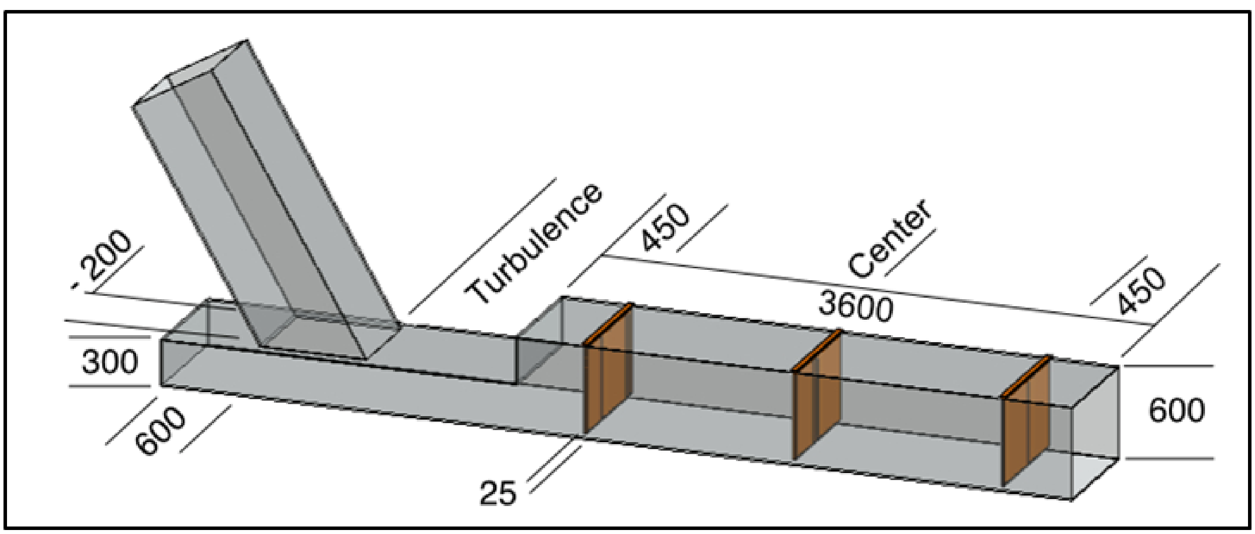
Air Speeding up to Go Under a Conventional Slit Exit Curtain
Blue is the Slowest Air Speed and Red the Fastest

A minimum slit width of 5 mm and critical curtain placement reduced this effect and resulted in recirculation inside the skirtboard enclosure. The closer you maintain the curtains to the load profile, the more efficient the skirtboard settling enclosure is. 25 mm is the recommended practice. Above 100 mm from the load the dust released was the same as if there were no curtains.



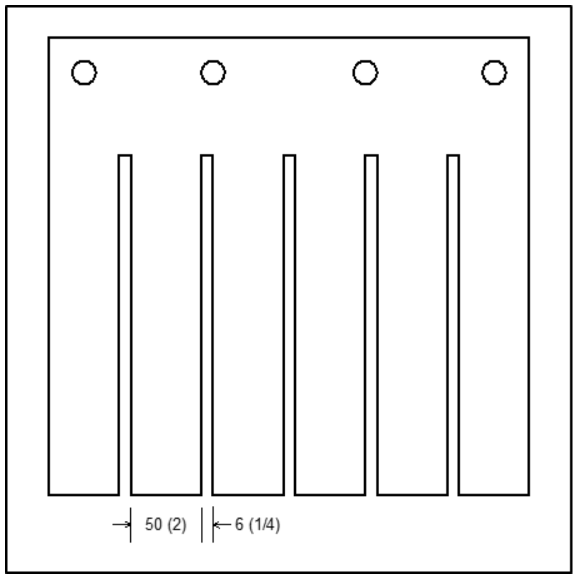
Example: 1200 mm Wide Belt Traveling 2 m/s with Wide Slit Curtains Placed to Create Recirculation within the 900 mm High by 4800 mm Long Chamber

In the example, the number of dust particles ejected per 100 particles injected (Surface Parameters) is counted. Injection #1 was for 100 m particles, #2 for 50 m, #3 for 40 m, #4 for 40 m, for 25 m, #5 for 10 m, and #6 for 1 m diameter particles of 1500 kg/m3 solid density. The output suggests that this arrangement reduced dust emissions by (600-47)/600 =92%.



Recommended Enclosure Design Based on CFD Analysis

It was found that making the chute to skirtboard junction narrower the step up from the impact area to the settling area helped set up recirculation in the settling portion. The location of the first and last curtains should be a minimum of 300 mm with 450 mm found to be optimum. At the inlet, this spacing encouraged recirculation flow and at the exit reduced air leakage at the sides, allowing a more uniform exhaust profile without speeding up the airflow. Placing the exit curtain inside the skirtboards also greatly reduces “popcorn” spillage compared to placing it at the exit. The turbulence length should be a minimum of 1.0 m long and more if the conveyor is sloped or if the material tends to roll back or bounce excessively at the impact point.



Dust Curtains with Wide Slits

Dust Bags

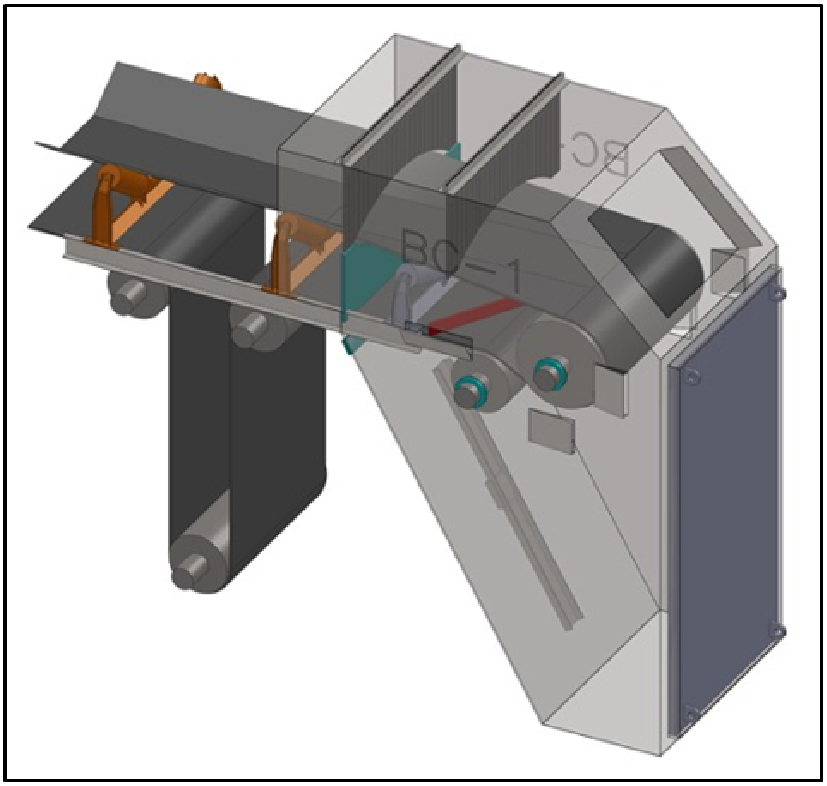
Particularly, when there is generated air it is common to put skirtboards the entire length of the conveyor because the passive or active system cannot handle the airflow. In these cases, dust collector bag or bags can be placed on top of the skirtboard enclosure to relieve some of the excess flow and allow the passive enclosure to work. Depending on the size of the bag, they can relieve up to 0.25 m3/s of air. The air flow inflates the bag. When the airflow stops, the bag collapses and caked material falls onto the belt. Dust bags work best on dry materials. They can be enclosed for weather protection and the cleaning is automated with a vibrator in cases where moisture reduces their effectiveness.

Dust Collector Bags Relieve Excess Air Flow Allowing the Passive System to Control Dust

Dust bags are selected based on the material being handled and the expected volume of air to be relieved. Typical air volumes that can be relieved are about 0.25 m3/s for a 300 mm and 0.53/s for a 600 mm diameter bag. The preferred location is 1/3 of the skirtboard extension length from the end of the skirtboard enclosure. A hole is cut in the skirtboard cover and a flange is attached. The bag is clamped to the flange and suspended upright. The bag must be of the type that can be grounded to reduce static cling and for dust that may be combustible. Approximately two meters of overhead space is required which may affect the mounting location. If subject to weather, the assembly can be enclosed in a “dog house.” Depending upon the material, the bag will self-empty when the airflow stops and the bag collapses or a vibrator can be attached to help discharge the caked material onto the receiving belt.

Transfer Point Sealing

Following the path of the bulk material through the system, the first location that requires sealing is the entry into the discharge chute. The goal is to reduce the amount of open area at the entrance to reduce the amount of air induced into the transfer point. It is recommended that two entry curtains be installed and the space between the top and bottom runs of the belt be blocked off as completely as possible. As with the skirtboard exit curtain, the first curtain should be inside the head chute 450 mm. It may be necessary to extend the head chute entry back to the first full troughing idler. The dribble chute exit seal should be about 50 mm from the belt to prevent the accumulation and buildup of fines from belt cleaner splash.



Idealized Discharge Chute

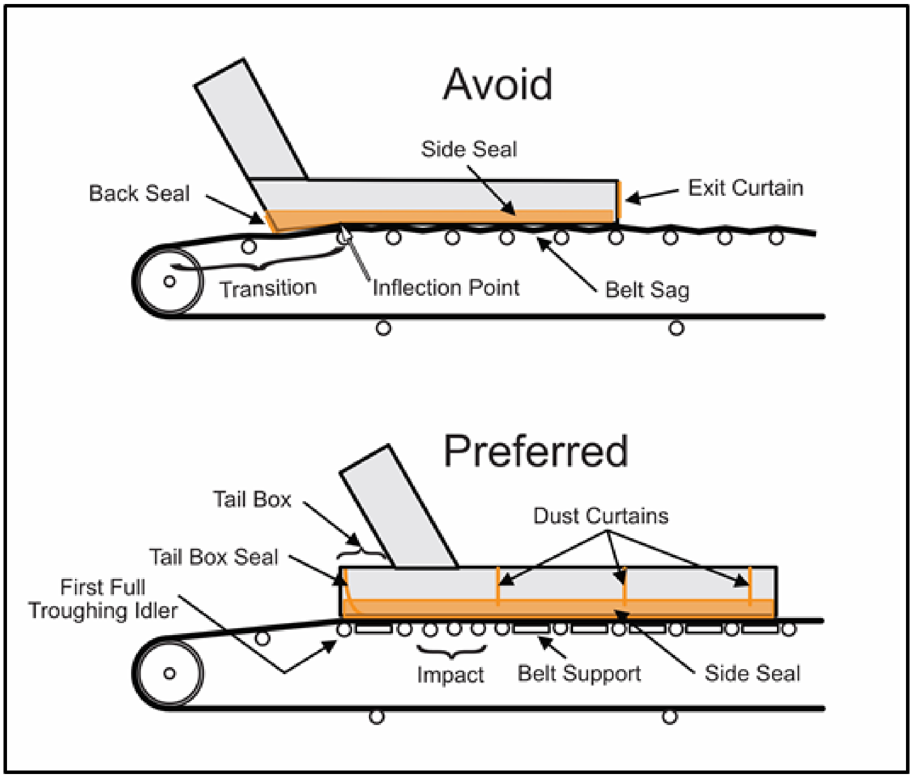
All other openings should be sealed as much as practical including access doors, shaft penetrations, and belt cleaner openings.

Skirtboard Sealing

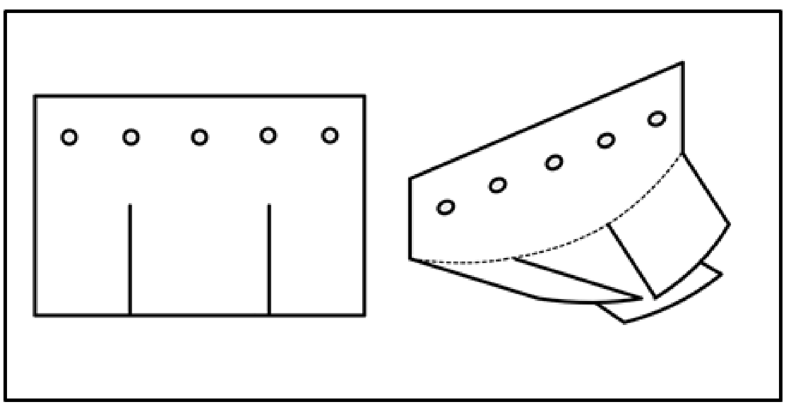
Sealing the skirtboards is much more effective if the loading does not start until the second fully troughed idler and the skirtboards extend past the loading chute toward the tail pulley at least 600 mm to create a tailbox. The purpose of the tailbox is to allow sealing at the impact point on the receiving belt and to prevent rollback of material from the rear of the transfer point. Extending the skirtboard walls allows the skirtboard seal to be run past the area of highest pressure from loading and allows the corners of the back of the skirtboards enclosure to be better sealed.

Crescent Shaped Wear Over Idlers
Caused by Loading on the Transition or Excessive Belt Sag

Loading before the belt is fully troughed is not good practice as the belt in the transition is not a stable flat surface that can be sealed. It is impossible to match the skirtboards and wearliner to the 3D curvature of the belt in this area. If loading occurs on the transition, the inflection point where the belt leaves the transition and enters the first full troughing idler is the main source of belt grooving and leakage at the skirtboard edges. Material that is against the liner in this area gets trapped in the inflection point as the belt transitions to a full trough. A characteristic crescent wear pattern forms above the first full troughing idler and becomes a leakage point. The material grinds away at the wearliner, sealing system, and the belt, allowing a gap that opens and allows dust and spillage to escape.

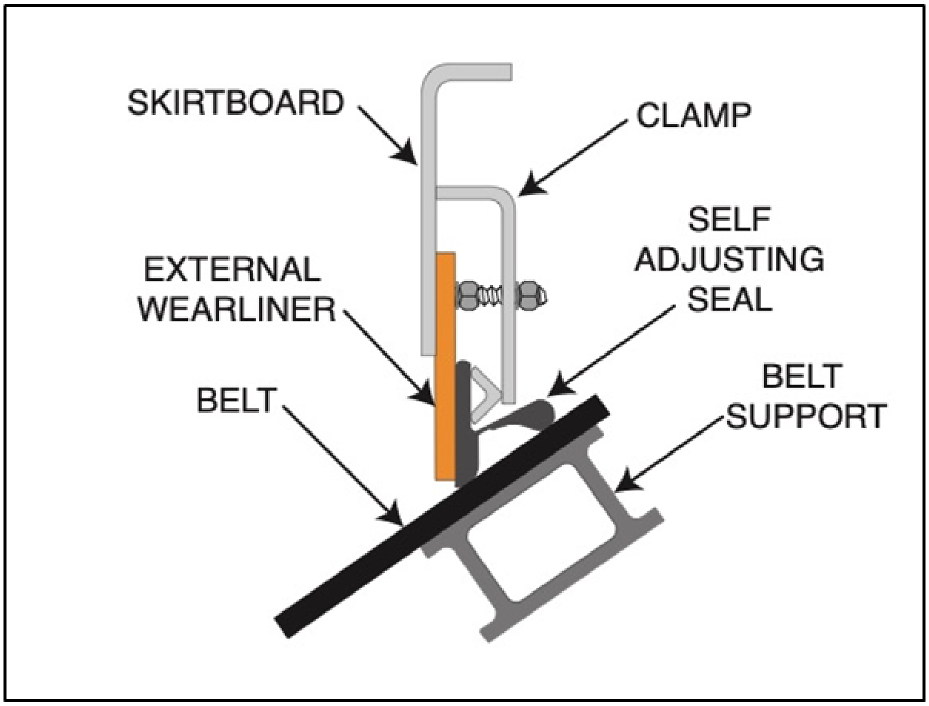


Loading After Fully Troughed is Preferred for Dust and Spillage Sealing



Tailbox End Seal – Fold to Fit Inside Rear of Tailbox

The side seals are for dust and small particle containment. The skirtboard side seals should be of a self-adjusting style that places minimal pressure on the belt. The side seals should be considered sacrificial and be of a lower abrasion index than the belt to avoid grooving the belt. A wearliner on the internal sides of the skirtboards is to take the pressure of the cargo loading off of the side seal and avoid trapping material between the skirtboards and the seal. The wearliner should be adjusted close to the belt and gradually taper in the direction of travel.



An Externally Mounted Wearliner is Easy to Adjust and Replace

Belt support under the belt in the entire load zone is important for maintaining a flat foundation for the sealing. There are many different options for belt support that either supports the whole troughed shape with impact beds or just the edge of the belt below the sealing system. A less efficient alternative is idlers close together under the impact area and then spaced no more than 600 mm apart for the rest of the skirtboard enclosure.

Conclusion

Engineering controls are the most effective way to reduce dust problems. Passive control techniques can virtually eliminate nuisance dust while reducing the emittance of respirable dust. The use of PPE may be necessary but their use can be much more easily managed in combination with a well-designed and maintained passive dust control system.

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ii 85% of Conveyor Maintenance is a result of Fugitive Materials Escaping from Transfer Points. 2014 Pit and Quarry Conveyor University Handbook MSHA Quote in Chapter 10

iii Hazard Prevention and Control in the Work Environment: Airborne Dust WHO/SDE/OEH/99.14 Chapter 1 - Dust: Definitions and Concepts

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v FOUNDATIONS 4th edition, 2012, Martin Engineering

vi Powder Technology 176 (2007) 77–87, Degradation characteristics of steel making materials during handling, R. Sahoo*

vii EPA Air Pollution Fact Sheet, EPA-452/F-03-009. www3.epa.gov/ttncatc1/dir1/fsetling.pdf

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Section - IV Active Dust Collection

Active dust control uses components and accessories to reduce the total emissions and require some form of external energy input or extract energy from the conveyor belt requiring additional power to overcome the added belt tension. There are three common techniques applied for active dust control: displacement ventilation, extraction ventilation, and material wetting. Displacement ventilation uses airflow to confine the dust source and keep it away from workers, reliably blowing dust downwind. Displacement ventilation is used almost exclusively in underground mining to keep workers upstream of the dust sources. Enclosing a transfer point between conveyors and using a dust collector is an example of extraction ventilation. Dust suppression using either plain water or water with chemical is an example of material wetting to control dust release. In surface bulk material handling, the operations usually don’t lend themselves to displacement ventilation so confinement with extraction or dust suppression treatments tend to be the most common engineering controls methods.

Extraction Ventilation

There are many types of dust collectors used to extract dusty air from enclosures in bulk material handling by conveyor. Besides energy consumption, there are two main issues with dust collectors, the collected dust has to be dealt with and the systems require maintenance. They tend to be either centralized dust collection systems where ductwork is run from the extraction points to a central dust collector, often called a bag house. Most designers use the Industrial Ventilation Manual, Conveyor Belt Ventilation Figure VS-50-20 for designing conveyor skirtboard extensions and extraction ventilation. Over the years, the different versions have varied little from The Air Hygiene Foundation recommendations in the 1940s.

The Industrial Ventilation Manual recommends designing for a 0.75 to 1.0 m/s indraft at all openings and a skirtboard extension two times belt width and 600 mm tall with an extraction point 1/3 of the distance from the exit. For dusty materials, an additional pickup at the tail of the transfer point is specified. Extraction volumes are based on per foot of belt width and belt speed and range from 0.25 to 0.75 m3/s. There are additional suggestions for drop heights over 1 meter, conveyors skirted the entire length for very dusty or light materials. The manual recommends one dust curtain at the exit of the skirtboard enclosure.

The Industrial Ventilation Manual approach does not require a calculation of induced, displaced, or generated airflow in the transfer point. Using belt speed as an indicator of the volume of air to be treated is a shortcut that does not take into account that induced air inflow is directly proportional to the open areas of the transfer point and proportional to the square root of the tonnage. As a guide, it is understandably conservative in its recommendations but CFD analysis shows that in most cases, the recommendations result in an overdesign that extracts all products 100 m and smaller. Once extracted, the material has to be dealt with at a central collection point and either disposed of or recycled.

Integrated Extraction

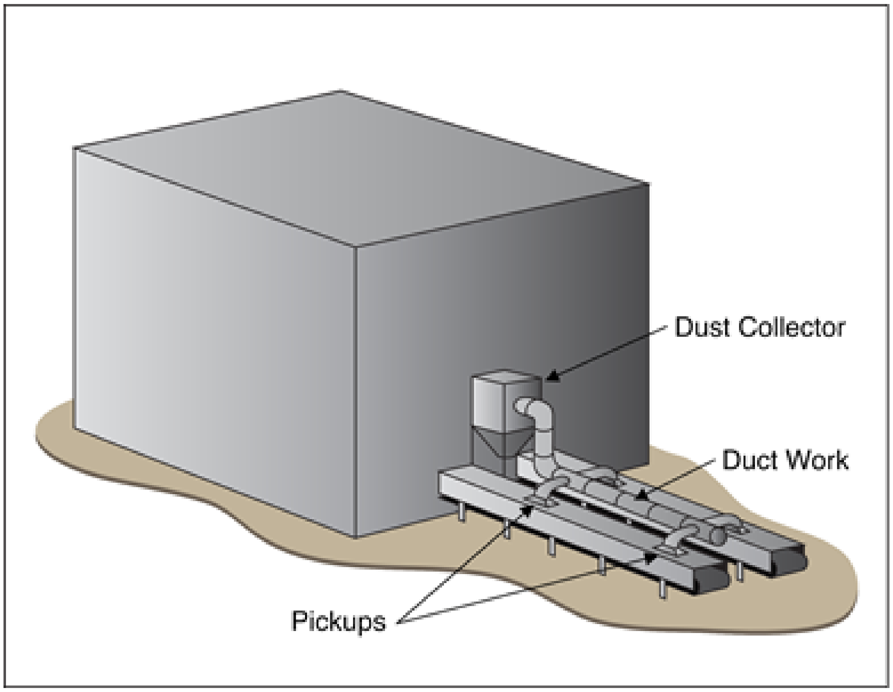
Integrated extraction is a modular approach to extraction ventilation or air filtering. With integrated extraction, the air is filtered on the conveyor and the amassed dust is returned directly to the belt. The filtering mechanism is much the same as in extraction ventilation utilizing cartridge or bag filter media and reverse jet cleaning and therefore the dust removal efficiency is similar.

Integrated Air Cleaners on Totally enclosed Air-Supported Conveyors

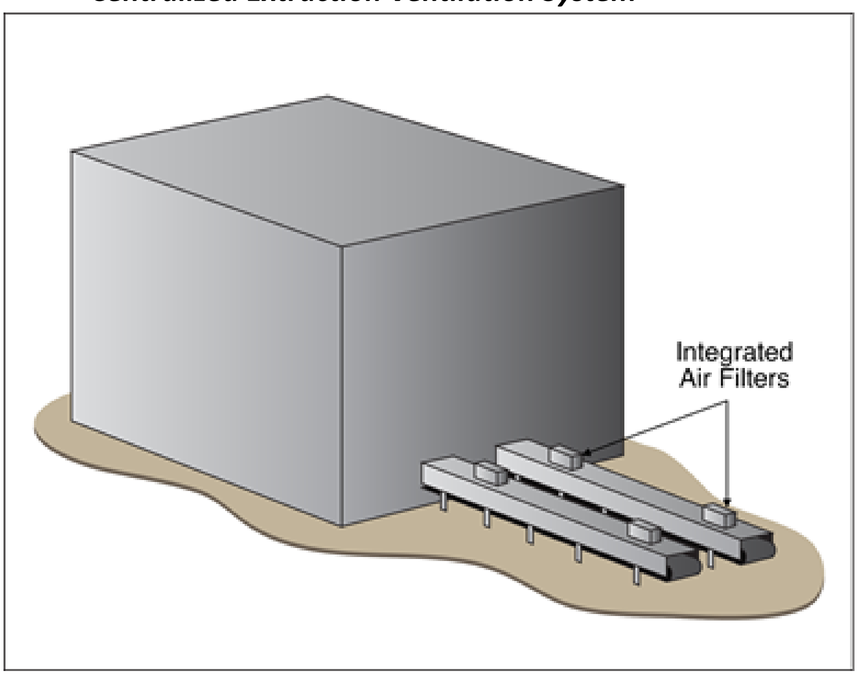
The integrated air cleaning system utilizes a series of independently operating assemblies at each dust generation point. The loss of a single unit will not result in an operation-wide shutdown of the dust collection system. This decentralized arrangement allows cleaners to be put into a maintenance cycle and each unit can be maintained at a time other than a plant-wide outage. The very nature of the design of the integrated air cleaner eliminates many of the disadvantages of a central dust collector while providing the same level of filtration.

A central dust collection system, though it is an industry-standard, has several attributes that make it undesirable. These attributes include, but are not limited to buildup 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 accommodated with recirculation or direct disposal.
The integrated approach eliminates many of the disadvantages of a centralized extraction system. The integrated system eliminates ductwork, so there is no chance of dust buildup, no balancing, and no duct maintenance. As the integrated system is a decentralized system utilizing air cleaners at each dust generation point. The integrated system is often more economical than centralized or unit systems. As the static pressure is much lower and there are no losses in pressure due to the ductwork, the fan motor is normally smaller than other systems. A comparison of two dust control options for Powder River coal with identical CFM requirements

shows the integrated approach realizes a 54% reduction in capital cost and a 26% reduction in power required.



Centralized Extraction Ventilation System



Modular Integrated Air Cleaner System

The integrated system will operate only when needed which reduces energy requirements. Because it can return the dust to the process, there is no need for a separate dust disposal system. Some bulk material dust is more valuable than the cargo. For these materials, the integrated air filter discharge can be directed to the side of the conveyor using a screw conveyor or other common means. Centralized bag houses often require confined space entry for service whereas modular integrated systems usually can be serviced without confined space entry.

Dust Suppression

Dust suppression involves the use of water to wet the bulk material to prevent the release of dust or to envelope the dust with a fine mist to cause dust particles to agglomerate, increase in mass, and fall from the air stream.

The most efficient use of water is at the point of size reduction to wet the bulk material and prevent the release of dust from the cargo. However, large quantities of water are required and the effect decreases rapidly as the water evaporates. Piping and pumping systems are expensive and moving water requires quite a bit of energy.

Using fine mists to control dust after it has been released reduces water consumption and is more efficient than deluging the material. The fine mist droplets should be close to the same size as the dust particles or the dust particles simply move out of the way and don't combine with the mist to cause the dust to fall out of the air stream. Misting systems are available for transfer points and wide area applications such as stacking and reclaiming or stockpile dust control. The main issue with fine misting and even using flood nozzles is that the quality of the water must be very good to prevent minerals in the water from clogging the spray nozzles.

The water of the quality needed for using spray nozzles is usually not available on site so the water must be filtered and the dissolved minerals removed or frequent maintenance is required. Water cannot be used in parts of many applications where the material has been processed and the finished product cannot be wet such as fertilizers and cement.

Surfactant chemicals can be added to the water to decrease the surface tension of the water droplets and improve the wetting of the dust particles, allowing them to agglomerate more easily. A variation of the use of surfactants is to create a foam with water, chemical, and compressed air. The application of foam is most often used in open systems like crushers to blanket the material and wet the dust. Surfactants have the benefit that they do tend to have residual effects that can last through several transfers or processes. The disadvantage to surfactants is primarily the cost of chemicals and compressed air. In some cases, final product quality requirements will not allow the use of chemicals to treat dust.

Excess Water used for Dust Control Can Create Slip, Trip, and Fall Incidents

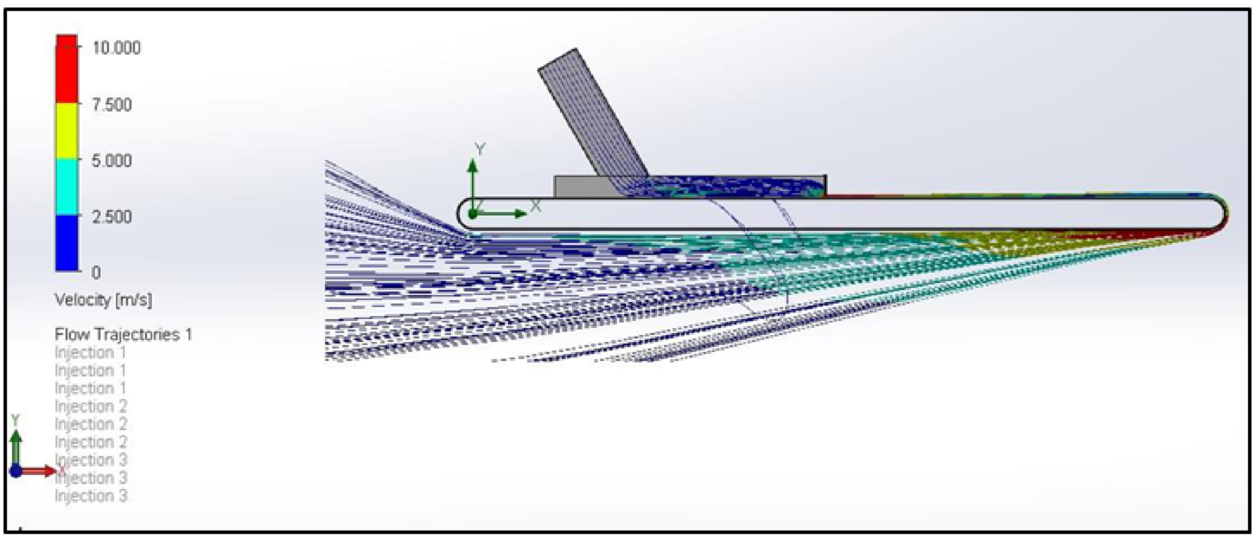
Excess water for dust control can lead to other safety, operational, and maintenance problems such as slips, trips, falls, chute plugging, and structural corrosion. Collection and treatment of the effluent require a secondary system such as channels or piping and settling basins.

Belt Cleaning

A properly selected and maintained belt cleaner system is an important element in dust control by reducing carryback to a tolerable level. It is best to rely on a manufacturer or very experienced supplier for recommendations as there are many factors to consider. A typical system for dust control will have several cleaners. Sometimes where belt cleaning is critical such as in underground coal mining, four or more cleaners are used on each belt head. In other applications, two belt cleaners are usually enough to do an adequate job. Belt cleaners must be installed correctly, inspected daily, and maintained frequently. Some manufacturers are offering remote monitoring and maintenance services for belt cleaning.

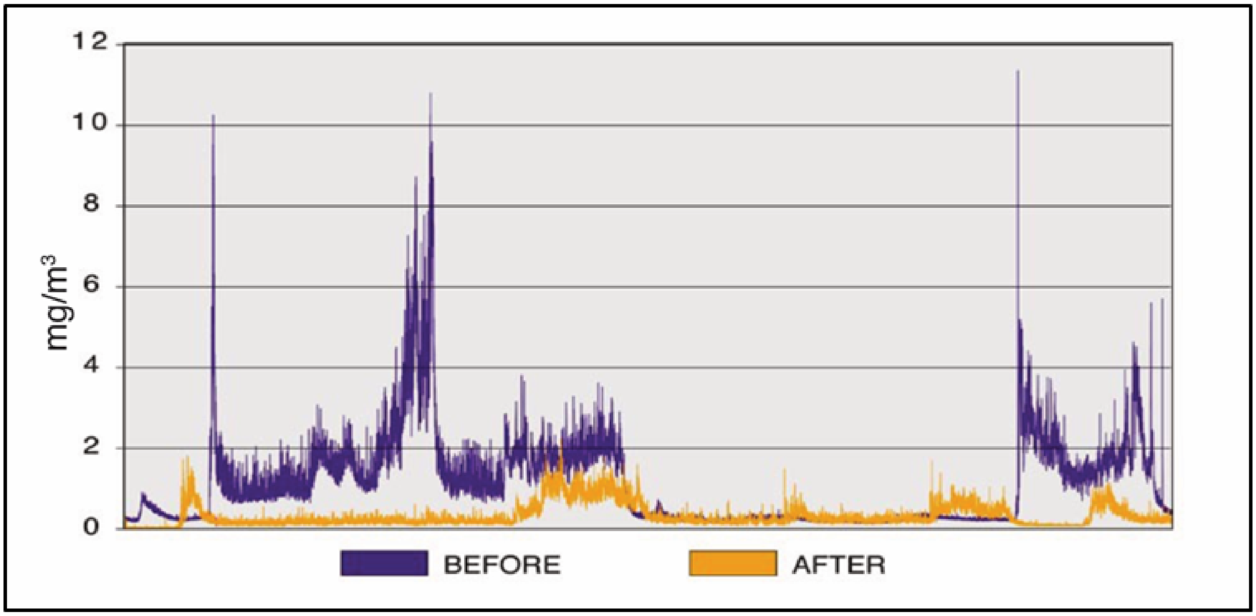
A typical conveyor in a mining or power generation application with a dual cleaning system that is properly installed and maintained will reduce the amount of carryback on the belt from an average of 500 g/m2 with no cleaners to less than 100 g/m2 of carryback on the belt's top surface. This reduction in carryback is a direct reduction in dust generation because the less carryback that remains on the belt, the less that is by the return idlers. The drier the carryback, the more of it that is released into the atmosphere, creating piles of muck under every return idler. If the surface of a belt in contact with the cargo is 1.0 meters wide and the belt travels 1.0 m/s a 100 g/m2, a layer of carryback represents a potential release of 360 kg/hr of dust per hour: [(1.0 m 1 m/s 3600 s/hr 100 g/m2)/1000 g/kg = 360 kg/hr]. If a conveyor runs empty for long periods, the carryback will dry out and be released mostly as dust.

Belt Cleaners work most efficiently when the carryback is wet or a little water is used periodically to keep the blades clean. If the bulk material is very dry, the cleaners may remove it but the air stream around the belt cleaner blade will cause the dry material to become airborne. If the cleaners are not located in the control enclosure, then the dust is released into the atmosphere. Some materials are attracted by static electricity and belt cleaning is difficult because the dust once removed by the cleaner tends to immediately reattach itself to the belt. In these cases, specialty systems involving a high-speed jet of air and a collection hood are the only option if water cannot be used to dissipate the static. Antistatic belts help but depend on the grounding of the entire system.



Dust Can be Carried Around the Conveyor and Become Airborne

If the belt is run for long periods of time, the carryback dries out and is dislodged by every idler or accessory the belt contacts. Often, belts are left running when they are not handling any material. There are process reasons but most of the time the reason given is to avoid peaks in the power demand which affect the peak demand charges. This is more of an excuse than a good management practice when it comes to dust control. Good dust control practice is to keep material on the belt while it is in operation.



Tripper in a Coal-Fired Power Plant Before and After Passive Dust Control. The Peaks in Data Occur when the Conveyor Ran Empty Without Coal

Conclusion

Active control systems require more maintenance than passive systems but they often reach 99.9% efficiency. Simple attention to detail like maintaining belt sealing and cleaning equipment, keeping inspection doors closed, and not running the belt empty for long periods of time is critical when it comes to controlling hazardous dust. Conveyor maintenance is notoriously reactive. Since many systems used to control fugitive materials are secondary to the ability to keep production going, the maintenance of these systems is almost always low on the priority list so maintenance is often nonexistent, until a citation is issued or there is a safety incident while cleaning up around the conveyor. Rarely is additional staff added when hazard control equipment is added. Outside contractors are often used for major maintenance but there is resistance to using them for routine transfer point maintenance, insisting they have the staff to do the work. Either way, maintenance of the dust control equipment must be a priority.

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