Beating the dust

Gerald Joy from the US National Institute for Occupational Safety and Health discusses practical ways to control dust in crushing, milling and screening operations

Size reduction and sorting of ore-bearing material is a part of almost every mineral extraction and preparation process. This activity is accomplished through some combination of crushing, milling and screening steps. The very nature of these treatments involves the transfer of energy to the ore; and almost always generates airborne dust.

Control of the dust generated by these operations can be achieved with proper analysis of the sources, identification of appropriate control technologies, and consistent application and maintenance of selected controls.

Uncontrolled airborne dust can create operational, environmental and worker-health concerns. Airborne dust becomes a health concern when it is present in sufficient quantities (based on the toxicities of its constituents), when it is of a size that can be inhaled deeply into the lung (termed 'respirable') and when it produces a harmful effect on deposition in the lung.

For mineral processing, exposure to quartz (crystalline silica) is often an occupational hygiene concern. Quartz is a very common mineral in the Earth's crust and inhalation of respirable quartz can lead to multiple serious diseases in humans.

This article focuses on prevention of occupational illness among workers through control of dust exposure, but the approaches discussed will contribute to reduction of detrimental operational and environmental consequences as well.

"Uncontrolled airborne dust can create operational, environmental and worker-health concerns"

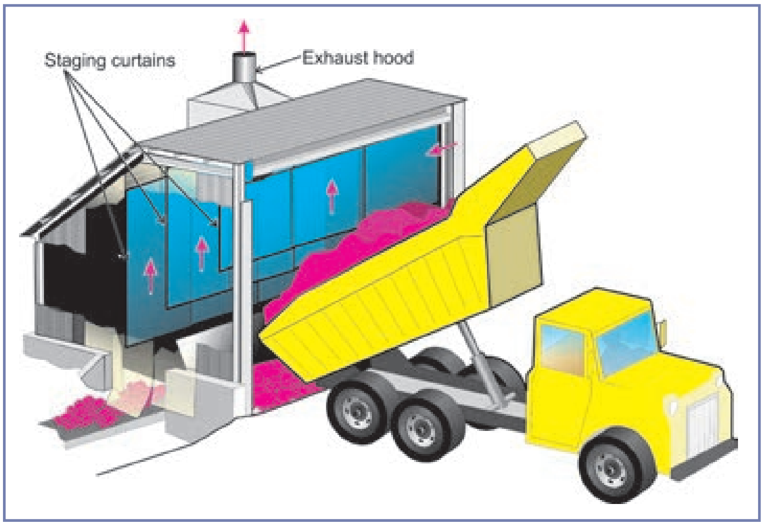
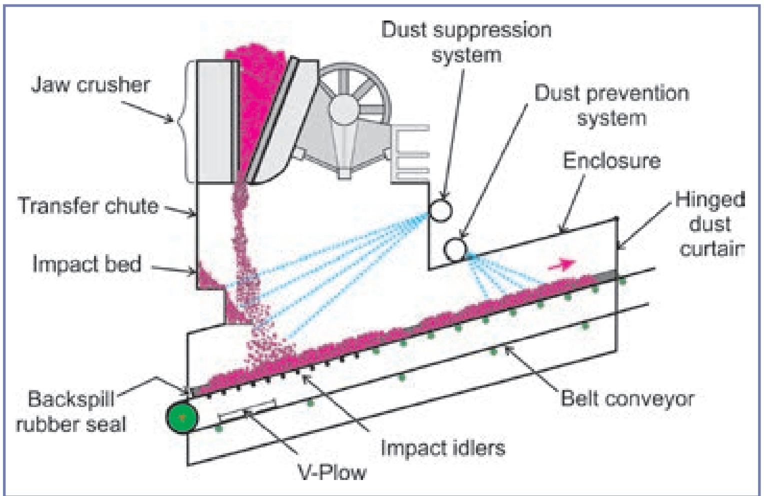


Illustration of a dry (exhaust ventilation) dust-control system with partial enclosure at a crusher dump loading operation



A wet dust-control approach on a crusher discharge/belt loading operation

CONTROL APPROACHES

Each installation of mineral-processing equipment will have its own unique characteristics, including the magnitude of dust emissions associated with its operation. The US Environmental Protection Agency has published a baseline ranking of dust emissions from crushers and screens, presented in the table. This shows how the application of dust controls can reduce the relative rate of dust emissions compared with primary crushing from 51 times to two times for subsequent crushers, and from 214 times to 12 times for screens. This illustrates just how important the selection of a dust-control method can be.

EPA comparison of dust emissions from dry and wet mineral-processing equipment

Equipment type	Relative dust emission rate (dry)	Relative dust emission rate (wet)
Primary crusher	1	1
Subsequent crusher	51	2
Screen	214	12

Prior to selecting a dust-control method, it will be useful to consider the range of approaches available. A generally recognised hierarchy of occupational exposure controls has been developed. This hierarchy lists five approaches ranked from most to least desirable on the basis of long-term effectiveness:

1 elimination of the hazardous material;
2 substitution with a less hazardous material;
3 engineering controls;
4 administrative controls; and
5 personal protective equipment (PPE).

When applied to mineral processing, it is apparent that neither elimination nor substitution are feasible approaches, as either would exclude the mineral ore the process exists to extract.

The next three approaches are commonly applied sequentially and often in combination to achieve an acceptable degree of risk reduction. That is, when an unacceptable degree of hazard remains after feasible engineering controls have been applied, administrative controls and/or PPE are implemented to achieve the desired degree of hazard reduction.

Engineering controls are the most

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An example of access doors arranged to minimise loss of material when opened

preferred of these three because a properly designed engineering control, such as an enclosed process, functions continuously without any input required from workers.

For administrative controls to be effective, supervisory personnel must continuously observe and enforce the administrative requirement. For example, if the selected control is to limit access to an unsafe area, supervisory staff must ensure that workers abide by the requirement and correct those who do not. PPE, which under ideal circumstances is highly effective, requires each worker to correctly perform multiple activities every time the equipment is used. The use of PPE also requires supervisory attention and maintenance of a parts inventory.

An important aspect of control selection is cost. Engineering controls are often capital expenditures, and understanding the direct costs of purchasing and installing these controls is straightforward. It is more difficult to fully capture the 'softer' costs of administrative controls and PPE. When rigorous analyses have been performed, the costs of these approaches have been surprisingly high.

> "When feasible, engineering controls should be the primary means of controlling occupat-ional exposures."

ENGINEERING CONTROLS

When feasible, engineering controls should be the primary means of controlling occupational exposures. In mineral processing, these controls can be broadly categorised into dry or wet methods. Dry dust-control methods typically involve full or partial enclosure of the dust source, and often include a local exhaust ventilation (LEV) system. Other facility infrastructure associated with this approach includes conveying duct work, a fan and usually an

Mills

Milling (or grinding) reduces material size through compression, abrasion and impaction. Tumbling mills are oriented horizontally, and motion is imparted to the charged material by rotating the shell of the mill. Stirring mills can be horizontally or vertically oriented and motion is imparted to the charged material by an internal stirring element.

Milling is often performed wet, but some commodities must be processed dry. In either case, because of the very small size of the milled product, the most important consideration for grinding circuits is dust containment, requiring complete enclosure of the mill and associated conveying equipment, particularly transfer points.

Design and work practices to minimise dust exposure from milling include:

- keeping the grinding circuit equipment tightly closed and maintained under a slight negative pressure 100% of the operational time by a dust-collection system – this means that any air leakage will flow into and not out from the equipment, keeping the dust contained;
- designing sampling points so that when the access doors are opened, the milled material stays inside – all sample and inspection doors should be installed at least 45° off the vertical or greater, with horizontal doors being preferable for easy access and lower risk of spillage;
- designing grinding circuits and buildings so that they can be washed down for cleaning;
- installing a vacuum system for clean-up – equipment should not be dry-swept or brushed off because of the possibility of dust liberation, and never use compressed air to clean equipment or work areas;
- having solid floors on upper levels around process equipment – if a spill or leak occurrs over a solid floor, it immediately piles up instead of falling towards the next level, where it will become airborne and contaminate the mill;
- isolating sections of the milling process to improve containment efforts – examples include uncovered storage, bagging areas and bulk load-out areas;
- keeping floors wet (above freezing conditions), so that any falling dust will immediately become wetted and trapped;
- for classifier circuits, following vendor guidelines for ducting and airflow to achieve optimum classification results – with other components of the grinding/load-out operation, the containment, pick-up points and ducting should be designed so that high air movement does not occur at transfer points and other potential disturbance areas where the air stream will entrain product; and
- anticipating that when new or recently lined tumbling mills are started up for the first time, the air leaving the mill is fairly humid until the grinding action builds up enough heat to drive off the moisture from the curing grout. This can lead to a build-up of moist material in the ducting and may cause blinded bags and cartridges in dust collectors. These problems will typically be resolved once the mill reaches operating temperature and the grout has cured.

air-cleaning component, such as a bag house.

LEV controls can be very effective when properly designed and conscientiously maintained. A dry system that employs exhaust ventilation can be expensive to install and requires energy to operate. However, dry systems come with other benefits in addition to dust control.

A dry system can capture fugitive material and return it to the process, reducing loss. Dry systems also conserve water, which is particularly important in arid locations.

When it is unfeasible to enclose or capture emissions from the dust source, and workers are required to be in the area, the inverse approach can be applied where the worker is provided with a clean environment by means of a ventilated cab or booth. This method is suitable when uncontrolled fugitive emissions will not result in unacceptable exposures to other workers or to the public.

Wet dust-control methods are often applied. These are relatively easy to install and can be inexpensive to operate, but their effectiveness varies widely. Other considerations for wet methods are the effect of added water on the handling of and subsequent treatment of the process material. Use of wet methods in cold climates will require freeze protection and may result in ice build-up that could create safety concerns.

Wet methods can be applied to prevent dust from becoming airborne, or to suppress dust that has already become airborne.

The prevention mode is almost always more effective. This is largely due to the difficulty of hitting airborne moving particles with other moving particles.

Crushers

Crushers reduce the size of feed material through the application of compression or impaction forces. For dust-control purposes, a crusher can be thought of as a black box with transfer points at both the input and output. Dust-control efforts, when necessary, must be applied to those two transfer points.

The dust controls applicable will vary widely to match the process configuration. Crushers can be fed by vehicles or by conveyor belts. Crusher output is typically transported by belts.

To minimise dust exposure from crushers, the following work practices can be observed:

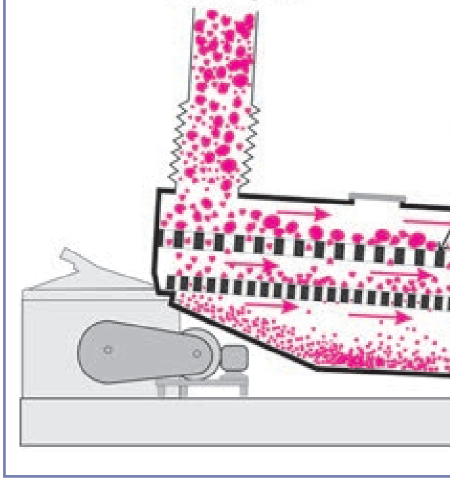
- maintain closure/locking devices such as clamps and other fasteners on doors and equipment inspection and access points. Fasteners are only effective when used;
- where compatible with the process, wash down areas on a periodic basis – periodic washing prevents the accumulation of material that can eventually become too large to wash down, necessitating a dry clean-up problem with the generation of dust;
- keep make-up air and recirculating air dust-filtration systems in place on operator booths, front-end loaders or other mobile equipment – ensure that only correct filters appropriate to the equipment are utilised, and maintain the systems to manufacturer specifications;
- wear approved respiratory protection when working in dust collectors, mills, air classifiers, screens and crushers;
- where feasible, automate the crushing process using sensing devices and/or video cameras – this removes the operator from the crusher area and reduces the potential for dust exposure; and
- where the crusher operation must be supervised continuously, provide an enclosed booth with a positive-pressure, filtered air supply for the operator.

Screens

Screening, normally performed on dry material, can produce high dust concentrations. This is due to the small size of the material handled and the vibration or rotation of the screen.

Screens should be totally enclosed and dust controls applied to any transfer points that must remain open. Necessary openings in the enclosure must be minimised and provided with tight-fitting enclosures. When using local exhaust to control dust on screens, the exhaust take-off point should be located so that desirable fines (product) are not collected. Work practices to minimise dust exposure from screens include:

- cleaning equipment and areas before and during work, when needed, preferably by washing or vacuuming;
- stopping material flow before cleaning screens, if feasible – the absence of flowing material minimises the potential for dust emissions;
- when cleaning, only opening the top or the bottom part of screen decks at a time (ie not opening both at the same time) – the larger the size of the opening, the less effective the ventilation system will be;
- only opening one screen at a time during cleaning – numerous openings decrease the capture effectiveness of a ventilation system;
- when cleaning screens, only using long-handled brushes that will provide more distance between the worker and the dust source;
- the use of variable-speed vibrators that significantly reduce the frequency of manual cleaning of screens – the less time cleaning screens, the less the potential for dust exposure;
- opening screen decks slowly to allow internal exhaust system to function at the deck periphery – rapid opening can cause a swirling effect with dust being released into the work area, potentially exposing personnel;
- not slamming screen decks closed – any material, no matter how slight, could become airborne due to the shock of deck closure;
- keeping decks clear of dust – a clean deck lessens the potential of dust emissions resulting from opening and closing decks, as well as from environmental factors such as wind;
- maintaining seals on screen decks; decks that are properly sealed should remain sealed when all fasteners and sealing materials are in place;
- properly maintaining and using closure and locking devices such as clamps and other fasteners must be well maintained; and
- where compatible with the process, washing down areas around screens periodically. Periodic washing removes material before it accumulates to a degree where dry clean-up methods become necessary. Dry clean-up activities present a much higher potential for worker exposure.



Generally, water spray nozzles used for prevention applications should be of solid or full-cone pattern, and nozzles for dust suppression should be of hollow cone or atomising type.

The effectiveness of controlling dust with water sprays can be improved through modification of the size of the water aerosol. When wetting bulk material for prevention, droplet sizes of 200-500μm are recommended. When suppressing airborne dust, droplet sizes of 10-150μm have been shown to be most effective.

Finally, water sprays can be used to move dust-containing air, essentially acting as small fans.

ADMINISTRATIVE CONTROLS

When feasible engineering controls do not achieve the desired level of performance, administrative controls are the next approach to consider.

Administrative controls modify the behaviour of potentially exposed workers. This can be achieved by training workers in ways they can minimise their exposure, by establishing procedures for performing work correctly and by defining and prohibiting unacceptable practices.

Administrative controls should be applied as necessary, but not over-applied. Selection of administrative controls is best accomplished as part of the output from a structured review of the process, such as a job hazard analysis.

When the review is performed by a mixed group of experienced workers and managers with contribution from appropriate subject-matter experts, valuable understanding regarding the sources and magnitude of various occupational safety and health hazards will result.

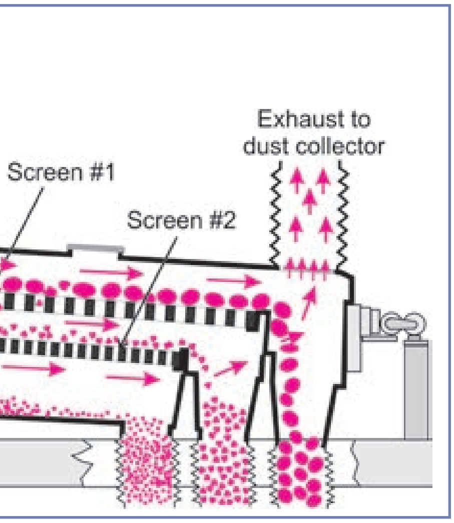


Illustration of a dry dust-control system on an inclined screen

PROTECTIVE EQUIPMENT

Finally, where feasible engineering and administrative controls have been applied, and worker exposure is not fully acceptable – or before these controls are fully installed – PPE can be used. PPE for the control of dust exposure is generally a combination of respiratory protection and cleanable or disposable work clothing.

Respirators are often considered to be inexpensive and easy to use. Actually, a competent respiratory protection programme is an involved process that includes training and medical surveillance of the relevant workers at a minimum.

Work clothing – either disposable or restricted to use inside controlled areas – is used to limit the spread of a hazardous substance, in this case quartz, so that office and support areas of the facility are not contaminated, and so that the worker does not carry the material home, where family members may be secondarily exposed.

Generally, PPE should not be required throughout a facility at all times. If this is the case, the situation indicates a general lack of control, and is a warning flag that should initiate further review. PPE is commonly necessary for work when normal controls must be bypassed on equipment that is being installed, maintained or repaired. If an area of the facility requires the use of PPE for entrance at any time, a restricted area (an administrative control) can be established to preclude exposure to non-essential workers.

SUMMARY

This article has discussed control approaches for a few of the several potential sources of dust emissions in mineral-processing operations. Specific requirements established by corporate and/or regulatory authorities may apply, and should always be observed.

While this information focused on crushers, mills and screens, other sources of dust exposure in mineral-processing facilities that may be of concern include conveyor transport – particularly transfer points, bagging and bulk loading – and the haul road and stockpile.

Information regarding control of dust emissions from these and other sources can be found in a recent publication from the US National Institute for Occupational Safety and Health (NIOSH) titled 'Dust Control Handbook for Industrial Minerals Mining and Processing'. The book was produced by NIOSH with contributions from the Industrial Minerals Association – North America (IMA-NA) and its member companies, and the US Mine Safety and Health Administration. The handbook is freely available from the websites of NIOSH and the IMA-NA.▼

"A competent respiratory protection programme is an involved process that includes training and medical surveillance of workers"

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