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Keeping Critical Spaces Clean Using Room Pressurization With Self-Maintaining Air Cleaners

Hazards are ever-present in the steel plant environment, and a heightened awareness and emphasis on safety is a necessary priority for our industry. This monthly column, coordinated by members of the AIST Safety & Health Technology Committee, focuses on procedures and practices to promote a safe working environment for everyone.

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Comments are welcome. If you have questions about this topic or other safety issues, please contact safetyfirst@aist.org. Please include your full name, company name, mailing address and email in all correspondence.

Room pressurization is used in many industries to prevent dust or other materials from entering critical spaces. Hospitals, laboratories and pharmaceutical manufacturers often use this method to maintain their clean rooms. In steel mills, employee health and safety, along with protecting equipment, are constant concerns when dealing with dust in this type of environment. In this article, health and equipment issues that are normally created by dust in a steel mill environment will be discussed as well as how positive pressurization can be used with a specific type of filtration to fix this problem.

There are many lung-related health hazards that are caused by breathing metal dust, and there are several costly equipment failures caused by metal dust. While most steel mills use heating, ventilation and air conditioning (HVAC) systems to attempt to keep these areas clean, this is inefficient and ineffective because these types of filters are not able to catch all of the dust particles. When these filters have dust on them it increases the static pressure resistance on the HVAC system and can reduce the amount of room pressurization.

By using positive pressure from a self-maintaining air cleaner, these spaces can be kept clean at a much lower cost and with better results. Positive pressure inside a room is effective in preventing dust from entering the room, and the use of a self-maintaining air cleaner provides effective filtration while creating the positive pressure environment.

Dust Hazards in the Steel Mill

Electric arc furnaces (EAFs) in steel mills produce dust made up of a variety of metals and other materials. Many of these materials are harmful to human health. These dusts present a health risk to anyone who has to work in areas such as operator pulpits where dust levels are high. In enclosed spaces like transformer vaults, motor control center rooms or other electrical rooms, conductive metal dusts can cause an arc flash hazard. All critical spaces require an extra level of protection from harmful dusts.

Health Risks From Steel Mill Dust

Steel mills produce metal dust that contains a mixture of large and small particles. The exact components of the dust depends on the type of steel and the process. In general, the most common metal found in steel mill dust is iron, followed by carbon, lime, zinc, manganese, calcium and silicon, but the dust often includes metals such as lead, arsenic and cobalt, which are highly toxic.[1] Gerdau Long Steel North America's material safety data sheet for steel mill EAF dust warns that inhalation can cause allergic reactions, cancer, lung damage, weakness, personality changes, kidney damage and problems with the brain and nervous system.[2]

The health hazards of all these materials are well known and the U.S. Occupational Safety and Health Administration (OSHA) has set limits on acceptable time-weighted exposures. However, employers and inspectors often measure these exposures in workers who are directly exposed to the fumes and material from the EAF. They may not measure the chronic exposure caused by long-term work in rooms full of accumulated dust. Metal dust particles can be as small as 0.3 micron and besides being easily inhaled, it can get on a worker's hands, into their clothes and onto their food. The health risks of daily long-term exposure to accumulated dust in the workspace may not be measured accurately.

In many areas of the steel mill, workers may not be exposed to harmful levels of this dust. However, in areas like control rooms, pulpits or other enclosed workspaces exposed to large amounts of dust, exposure can be heavy. Dust that accumulates in these enclosed spaces can be hard to remove, and an ordinary HVAC system is not designed to handle a heavy load of metal dust. The amount of dust and particulate produced by arc furnaces and other steel mill processes is far in excess of what a typical HVAC filter is meant to deal with.

A typical HVAC filter is designed to capture particles sized at 3–10 microns with 20% efficiency (MERV 5). A self-maintaining air cleaner filter is designed to capture particles size at 0.30 micron with 99.999% efficiency (MERV 15). All filters are rated by the minimum efficiency reporting value (MERV) rating standard set forth by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).

The MERV rating system is a value that indicates the size of particles an air filter is designed to capture. Higher MERV ratings are more effective at capturing smaller particles. That's why hospitals tend to use MERV 16 or higher, so the most pollutants possible can be captured. The ASHRAE designed the MERV rating and advises the use of filters with minimum MERV ratings of 6. The U.S. Department of Energy recommends a minimum of MERV 13.

- MERV 1 to 4 — Less than 20% of particles (>10 microns) are captured.
- MERV 5 to 8 — Less than 20%–60% of particles (3–10 microns) are captured.
- MERV 9 to 12 — 40%–85% of particles (1–3 microns) are captured.
- MERV 13 to 16 — 70%–98% of particles (0.30–1.0 micron) are captured.
- MERV 17 to 20 — Even the smallest particles (<0.3 micron) are captured.

Workers in enclosed areas such as operator pulpits with insufficient dust control are at risk of lung diseases such as siderosis, silicosis, black lung and lung cancer from inhaling dust throughout the workday. They are also at risk of neurological damage from lead and manganese. These conditions become worse with heavier or longer exposure, and they can be permanent. Because of these health risks, it's important to keep dust out of these workspaces. It's common for HVAC filters to be used for this purpose, but they will often fail within a matter of days and need to be replaced. These filters also may not be efficient enough to capture the small particles of metal dust, and the smallest particles are the most dangerous because they are inhaled the most deeply into the lungs. While high-efficiency particulate air (HEPA) filters can capture these small particles, they also often fail within a few weeks or months from the volume of dust being filtered through them.

In addition to the health risks of this dust, it also creates an unpleasant and difficult working environment. Dust throughout a workspace can get into expensive equipment like computers, clog HVAC vents, and get all over the clothes, tools and equipment used by the workers. This accumulation of dust is not only unpleasant but can make it more difficult for workers to do their jobs. In a room without positive pressure, someone opening a door might sweep in a cloud of dust with their entry, so that over time the

Table 1

Section of Material Safety Data Sheet for Steel Mill Electric Arc Furnace Dust[2]

CAS #	Component	Percent
1309-37-1	Iron oxide	0–35
1305-78-8	Calcium oxide	0–35
1314-13-2	Zinc oxide	0–25
14464-46-1	Silica, cristobalite	0–15
7439-96-5	Manganese	5–10
1309-48-4	Magnesium oxide fume	5–10
7440-31-5	Tin	0–5
1344-28-1	Aluminum oxide	0–5
7440-47-3	Chromium	0–5
1314-56-3	Phosphorus pentoxide	0–5
7446-09-5	Sulfur dioxide	0–5
7789-75-5	Calcium fluoride (CaF_2)	0–5
7782-41-4	Fluorine	0–5
7489-98-7	Molybdenum	0–5
7440-22-4	Silver	0–5
1314-62-1	Vanadium pentoxide	0–5
7440-38-2	Arsenic	0–5

Table 2

ANSI/ASHRAE MERV Standard 52.2-2012

MERV Std. 52.2	Intended Dust Spot Efficiency Std. 52.1 (2)	Average arrestance	Particle size ranges	Typical applications	Typical filter type
1–4	<20%	60–80%	>10.0 µm	• Residential/minimum • Light commercial/minimum • Minimum equipment protection	• Permanent/self charging (passive) • Washable/metal, foam/synthetics • Disposable panels • Fiberglass/synthetics
5–8	<20–60%	80–95%	3.0–10.0 µm	• Industrial workplaces • Commercial • Better/residential • Paint booth/finishing	• Pleated filters • Extended surface filters • Media panel filters
9–12	40–85%	>90–98%	1.0–3.0 µm	• Superior/residential • Better/industrial workplaces • Better/commercial buildings	• Non-supported/pocket filter/rigid box • Rigid cell/cartridge • V-cells
13–16	70–98%	>95–99%	0.3–1.0 µm	• Smoke removal • General surgery • Hospitals and health care • Superior/commercial buildings	• Rigid cell/cartridge • Rigid box/non-supported/pocket filter • V-cells
MERV Std. 52.2	Efficiency			Typical applications	Typical filter type
17–20[1] *Deleted from ASHRAE*	99.97%–99.9999%			• Hospital surgery suites • Clean rooms • Hazardous biological contaminants • Nuclear material	• HEPA • ULPA

Note: This table is intended to be a general guide to filter use and does not address specific applications or individual filter performance in a given application. Refer to manufacturer test results for additional information.

(1) ASHRAE does not have a test procedure for HEPA testing and has thus dropped the MERV 17–20 classifications.

(2) ANSI/ASHRAE 52.1 ranges are provided for reference only. The NSI/ASHRAE 52.1 Standard was discontinued as of January 2009.

accumulation becomes more and more problematic and costly to clean up.

Arc Flash Risks From Steel Mill Dust in Motor Control Center Rooms

Steel mills contain many types of electrical equipment that could act as ignition sources when surrounded by conductive metal dust. A few examples are transformer vaults and motor control centers, which need to be protected from conductive metal dust entering the room. Sparks from electrical equipment can ignite accumulated dust and create arc flash hazards.

In addition to the risk of electrical equipment causing arc flash hazards and threatening the lives of the personnel around them, there is also a threat of destroying expensive equipment and the cost associated with the downtime due to such an event. Valuable equipment could be damaged and, in the worst-case scenario, lives could be lost.

With the presence of large electrical equipment like transformer vaults, there is high potential for an electrical spark to ignite any dust that has accumulated in the room. Transformers especially involve very large amounts of electricity with significant potential to act as an ignition source. Also, these types of rooms tend to be very large and, therefore, difficult to clean once dust has been allowed to accumulate. The best solution is to prevent dust from entering the rooms at all.

As indicated in Table 3, the National Fire Protection Association (NFPA) recommends that if dust has accumulated to one to two times the threshold for allowable dust accumulation, it should be cleaned up within 8 hours on easily accessible surfaces and within 24 hours on hard-to-reach surfaces. If the accumulated amount is greater than four times the allowable amount, it must be cleaned up within one hour of reaching that amount. These numbers

Table 3

National Fire Protection Association (NFPA) 484 Maximum Time for Cleanup of Metal Dust[3]

Accumulation on the worst single square meter of surface	Longest time to complete unscheduled local cleaning of floor-accessible surfaces	Longest time to complete unscheduled cleaning of remote surfaces
>1 to 2 times threshold dust mass/accumulation	8 hours	24 hours
>2 to 4 times threshold dust mass/accumulation	4 hours	12 hours
>4 times threshold dust mass/accumulation	1 hour	3 hours

assume that the facility is clean, and that the accumulation is caused by a leak or sudden release of dust. By NFPA standards, a facility should never have a long-term consistent accumulation of dust at or above the threshold limit.[3]

Unfortunately, in many facilities, dust can accumulate at possibly dangerous levels for years, not hours. In Fig. 1, dust is present on the floor, but the dust inside or under the panels is not seen. In a room like a motor control center room or a transformer room, just a spark from an electrical source could create an arc flash. As shown in Fig. 1, accumulation of dust on the floor in this space is a problem, but it seems likely that the exposed floor is still cleaned more often than under, on top of, or behind the equipment, where the accumulation could have reached dangerous levels.

Positive Pressure as a Solution to Dust Issues in Critical Spaces

What Does It Mean to Create Positive Pressure in a Space? — Positive pressure simply means that the pressure inside the space is greater than the pressure outside. For this to be accomplished, the space must be enclosed well enough that the increased volume of air will stay inside. Doors opening and closing should not create significant pressure loss, but doors or windows cannot be left open. For positive pressure in a room to be effective, the pressure must be maintained, and if the pressure is allowed to drop, dust will start entering the space again.

All HVAC and other airflow systems are designed for a certain number of air changes, which is how often the air in that space is replaced by clean air. For areas in a steel mill or other metal manufacturing facilities, the number of air changes per hour may be anywhere between 10 and 20, depending on how heavy the air contamination is.[4] The appropriate number of air changes is determined by what is required to maintain clean air.

$$q = nV \tag{Eq. 1}$$

where

q = fresh air supply (ft^3/h, m^3/h),
n = air change rate (h^{-1}) and
V = volume of room (ft^3, m^3).

The formula shown in Eq. 1 allows system designers to calculate how much airflow is necessary to create enough air changes per hour for the space and the level of air contamination. This usually leads to replacing the same volume of air that is removed, leading to neutral pressure. Under neutral pressure, air can flow freely in either direction, in or out of the room, carrying dust and particulate with it.

Positive pressure is achieved by having more air flowing into the room than the amount of air being removed from the room. This creates a pressure differential between the inside and outside spaces. Differential pressure in settings like steel mills is recommended to be no less than 0.02 inch of water gauge

Figure 1

Dust accumulation in a motor control center.

and preferably higher.[5] This is achieved by developing a system that will add more air to the room than the air that is being removed. In most settings, both the removed air and the return air are filtered to remove contaminants and dust.

Because airflows from areas of higher pressure to lower pressure, the positive pressure inside a space will be constantly pushing back against contaminated air and dust that might enter the space. With air trying to flow out of the high-pressure area, it will create a flow outward every time a door is opened, or through any openings in the room.

Purpose of Positive Pressurizing a Room

Positive room pressure is frequently used in hospitals and other medical settings where contamination of clean space could be a problem. Laboratories and pharmaceutical manufacturers also commonly use this technique to maintain clean space where contamination from outside must be avoided.

Figure 2

Standard HVAC filtering motor control center.

This concept can be applied to steel mills and the critical spaces that need to be kept as free of dust as possible. Rooms in a steel mill don't need to be as clean as a hospital room, but a hospital atmosphere will not put nearly as much strain on the filtration system as the air in a steel mill. Keeping a room under positive pressure keeps dust from entering. Whenever a door is opened, air will try to flow outward, pushing back against dirty air that might flow in.

Positive pressure to prevent dust from entering a room is a much easier solution than trying to keep it clean with housekeeping measures. In an environment like a steel mill, keeping critical spaces as clean as they need to be would require constant dust cleanup. Not only is this a waste of time and resources, but also might leave dust accumulated in hard-to-reach but common places like overhead beams or ceiling tiles. Positive pressure greatly reduces or eliminates the need for cleaning because it keeps dust from entering. It also decreases the health risks to employees and the potential for dust hazards.

Equipment for Creating Positive Pressure

Many facilities create positive pressure using an HVAC system with standard filters that are typically rated as MERV 5. For medical or laboratory facilities, HEPA filters that are rated as MERV 17–20 are also used for their very high filtration efficiency. This type of system, however, is not ideal for use in a steel mill. The airborne dust load in a steel mill is far higher than would be found in those settings. Standard HVAC filters are not designed to deal with this type of dust load. They will quickly become overwhelmed with dust and will start to block airflow through the system as well as allowing smaller dust particles through the filters, as illustrated in Fig. 2.

It is common for the HVAC filters to require changing once a week or even once a day. Besides the expense of constant filter changes, steel mills also must deal with the time and labor required to change these filters, as well as the cost of disposal since the filters may contain hazardous materials.

Self-Maintaining Air Cleaners

One solution to this problem has recently been developed: the self-maintaining air cleaner. Instead of HVAC or HEPA filters, these dust collectors use round cartridge filters that hang vertically from a tube sheet. These systems are called "self-maintaining" because the filters are cleaned by pulses of compressed air. As a result, they do not require manual cleaning. The filters meet the recommended efficiency of MERV 155, which means they are efficient for particles as small as 0.3 micron.

Fig. 3 shows the pulse jets above the filters. These jets pulse compressed air through the filters, keeping them functioning and maintenance-free for much longer than other types of filtration systems. Many steel mills using these systems for positive pressure areas can see filter life of one year or more. Unlike HEPA filters, the cartridge-style filters are designed for heavier dust load applications.

These systems serve two functions. First, they filter the dust out of the air through the MERV 15 cartridge filters, removing dust and contaminants. Second, they provide clean, filtered air to the room. While they do this, the fans add enough air to create positive pressure inside the room. Common locations for self-maintaining air systems include transformer vaults, motor control centers, server rooms, hydraulic rooms, operator control pulpits, compressor rooms and reactor vaults.

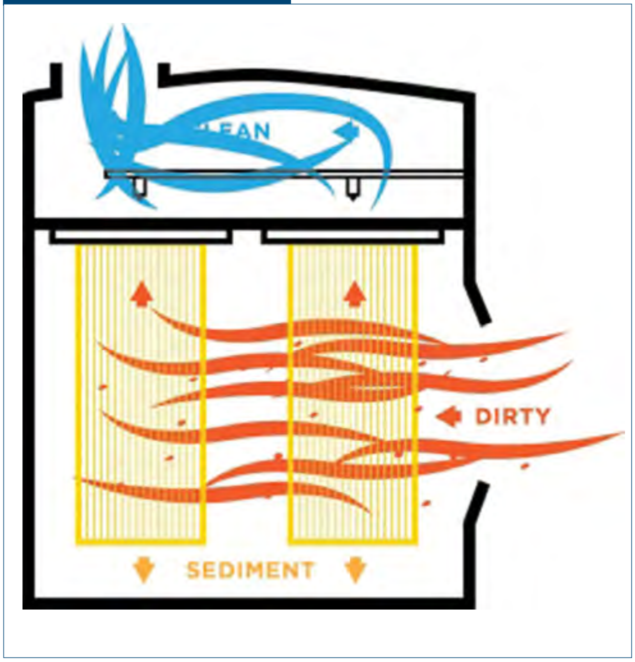
A system of this type is illustrated in Fig. 4. The drums beneath the air cleaner collect dust, which is then disposed of. The filters are accessed through a door for replacement. Also shown is the air inlet, which takes in ambient air from outside into the air cleaner to be filtered. As seen in this photo, these self-maintaining air cleaners can be placed in a variety of locations. This one creates positive pressure inside a transformer vault. It is rated for approximately 16,000 cubic feet per minute with a fan operating at 7 inches of water column, resulting in a 3.8-to-1 air-to-cloth ratio. It has 12 cartridge-style filters.

Depending upon the size of the space and the number of air changes per hour required, self-maintaining air cleaners can be designed in a variety of sizes. Another option is the choice between constant airflow and a variable frequency drive. The variable frequency drive is connected to a sensor that detects loss of pressure in the room, such as when the door is opened. This signals the fan to increase the airflow. With constant airflow, the room will still maintain positive pressure, although it may not return to full pressure as quickly after a loss.

The main advantage to using a self-maintaining air cleaner is the greatly decreased requirement for maintenance and filter changes. Unlike an HVAC system, these systems are designed for heavy dust loads, whether they are filtering air from outside or from inside the facility. HEPA filters in these applications tend to become quickly clogged with dust, but when they are used as secondary filters in a self-maintaining air cleaner system, the MERV 15 filters capture most dust and the HEPA secondary filters may last years instead of months.

The same equipment that functions as a self-maintaining air cleaner, taking in ambient air for room pressurization, can also serve as a more standard dust collector, taking dirty air from inside the facility and filtering it before venting or returning it. To maintain positive pressure with this type of use, ambient air will have to be added back into the building along with the filtered air in order to maintain positive pressure.

Figure 3



Internal view of a self-maintaining air cleaner.

Figure 4

Self-maintaining air cleaner installed on exterior of steel mill.

Conclusion

Steel mills are challenging environments for dust control. Equipment such as EAFs produce large amounts of dust, and this dust can be hazardous to worker health and equipment. Critical spaces in steel mills must be kept free of dust. These spaces include those that contain critical equipment and electronics, such as transformer vaults, motor control centers, etc. They also include spaces such as control pulpits where steel mill personnel are present. The most effective solution to keeping these spaces clean is to keep them under positive pressure.

While HVAC filters are often used for filtration in these settings, a more efficient and effective method is the use of a self-maintaining air cleaner system. This type of system is able to create positive pressure in critical spaces while also increasing filter life and decreasing maintenance cost and time. The positive pressure created by the system prevents dust from entering the room and maintains a clean space.

References

1. Rizescu, C.Z.; Backinschi, Z.; Stoian, E.V.; and Poinescu, A.A.,"Characterization of Steel Mill Electric Arc Furnace Dust," *Journal of Hazardous Materials*, Vol. 109, Nos. 1–3, June 2004, pp. 59–70.
2. Gerdau Long Steel North America, "Material Safety Data Sheet, Material Name: Steel Mill Electric Arc Furnace Dust," 2013.
3. Engineering Toolbox, "Air Change Rates in Typical Rooms and Buildings," 2005, www.engineeringtoolbox.com/air-change-rate-room-d_867.html.
4. Noll, J.; Cecala, A.; and Hummer, J., "Instituting a Filtration/Pressurization System to Reduce Dust Concentrations in a Control Room at a Mineral Processing Plant," *Mining Engineering*, Vol. 67, No. 12, December 2015, pp. 42–48. ✦

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