WHITE PAPER

Reducing Thermal Spray Hazards with Proper Dust Collection

By Taylor Morgan

camfil
AIR POLLUTION CONTROL

Thermal spray processes generate a wide range of contaminants that threaten worker health and safety if not properly controlled. Is your facility at risk? This white paper reviews the hazards and describes how to design a dust collection system that is specifically engineered to your thermal spray application – a system that will minimize risks and ensure regulatory compliance while also controlling costs.

Reducing Thermal Spray Hazards with Proper Dust Collection

By Taylor Morgan

Thermal spray involves many processes using different equipment, materials, gases, powders and wires. High efficiency cartridge-style dust collectors are the technology of choice for controlling harmful particulate emissions generated during thermal spray operations. Each process has a different dust-loading volume going into the dust collector based on hours of operation, the size of the targets, the properties of the powders/wires, and feed rate of the materials used, which may react differently in the dust collector. You must fully understand all of the moving parts involved in the process to engineer the correct dust collection solution for the application.

This white paper will review the numerous health and safety risks associated with thermal spraying and will outline steps for the proper design and maintenance of a dust collection system to reduce these hazards.

Dust collector used on a spray and fuse application incorporates an explosion vent and isolation valve due to the combustible material in the spray process.

Health and Emission Hazards

The fine dust particles generated during powder spraying can contain a variety of metals with potential health risks. The primary route of entry is the respiratory system: Other possible routes are eyes, ingestion, and/or skin contact. The Material Safety Data Sheets (MSDS) are a good starting point for identifying which metals occur in your processes. OSHA has established permissible exposure limits (PELs) based on 8-hour time weighted average for hundreds of dusts, including the numerous metals generated during thermal spray operations.

Nickel: Nickel is the most commonly encountered allergen and is classified as a potential occupational carcinogen by NIOSH and as a carcinogen on IARC and NTP lists. Exposure to nickel and nickel oxide may cause metallic taste, nausea, tightness in the chest, fever and allergic reactions. Long-term overexposure may cause lung fibrosis or pneumoconiosis. The eyes and skin may also be affected.

Cobalt: Cobalt exposure can trigger skin diseases such as contact eczema and dermatitis, and respiratory irritation or decreased pulmonary function with diffuse nodular fibrosis. It is a potential occupational carcinogen for humans

HVOF and plasma spray booth with dust collection.

and can interfere with the metabolism of thyroid hormones.

Copper: Copper exposure is associated with eye irritation and decreased respiratory functions, with the appearance of cough and dyspnea. It is classified as a potential occupational carcinogen for humans.

Aluminum: Prolonged inhalation of aluminum may provoke respiratory problems, from a simple cough to acute pulmonary edema. Some rare cases of pulmonary fibrosis have been reported.

Hexavalent chromium: Hexavalent chromium, also called chromium VI or hex chrome, is a carcinogen with a long list of adverse health effects. It can be produced by plasma-arc, flame (including HVOF), and electric-arc spray processes. Almost any chromium-bearing material can produce the hexavalent state when exposed to the high energy levels associated with thermal spraying. Chromium oxide, MCrAlYs and nickel-chrome are among the materials that produce hex chrome when sprayed.

Hex chrome overexposure can result in short-term upper respiratory symptoms, eye or skin irritations. Long-term, the greatest health danger associated with hex chrome exposure is lung cancer. Other major health effects include damage to the upper respiratory system, and allergic and irritant contact dermatitis. Respiratory tract problems can include inhalation damage to mucus membranes, perforation of septum tissue between the nostrils of the nose, and damage to the lungs. In addition, there may be injury to the eyes, skin, liver and kidneys. Once in the body, hex chrome typically targets some of the body's organs. A worker exposed to hex chrome may also experience symptoms such as sinus irritation, nosebleeds, stomach and nose ulcers, skin rash, chest tightness, wheezing and shortness of breath. The current OSHA PEL for hex chrome is extremely stringent, at 5.0 µg/ m3 (micrograms per cubic meter). Respirators and controlled clothing are required for individuals who are exposed above this threshold.

Conduct air sampling to characterize worker exposure to airborne contaminants and determine whether metal fumes, dusts, gases, and vapors are at concentrations that exceed allowable limits. Ensure that workers are not exposed to exhaust gases from the thermal metal sprayer's power generator. Some companies take it a step further to have bloodwork on their employees to ensure the levels of metal are not affecting their health.

Combustible Dust Fire and Explosion Hazards

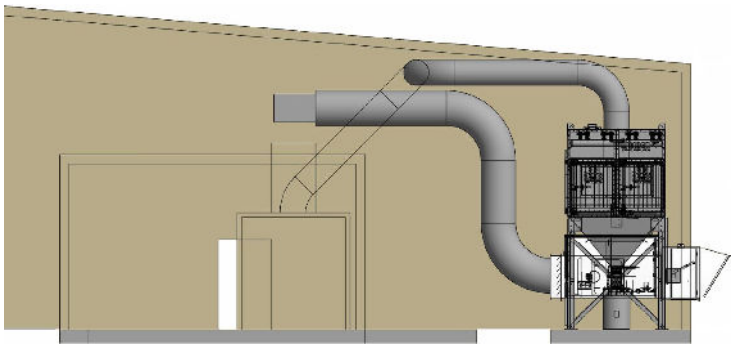
Inhalation or other absorption of harmful metal dusts by workers is a critical concern, but it is not the only concern. Metal dust particles in the air in the right concentrations can also create an explosion hazard. Dust samples should undergo testing to determine combustible and explosive properties. Explosibility testing is essential in identifying the best dust collection system for an application as well as the explosion protection or prevention equipment to use on the dust collector and related components.

Various factors such as the metal's purity and the presence of by-products, moisture, and oxides may affect the explosivity of an alloy's dust.

A hazard analysis, conducted by an engineer knowledgeable about the process, will also be needed to identify the full range of combustible dust deflagration, fire and explosion hazards specific to the application. Methods for hazard analysis relating to metal dusts are spelled out in NFPA 484: Standard for Combustible Metals. Readers are also urged to become familiar with the recently published NFPA 652: Standard on the Fundamentals of Combustible Dust, which introduces the concept of Dust Hazard Analysis (DHA), a new simplified methodology targeted toward factories involved in more basic processes involving simple dust collection systems.

General Design Considerations for Powder/ Wire, Gas and Dust Control

Powder and dust control are mainly provided by the dust collection system; however, some issues are more specifically related to booth structure and controls.



Schematic view of plasma spray booth with 24-cartridge dust collector and heated makeup air system.

The booth design needs to be linked with good ventilation flow and control. During the early design decisions regarding booth, coating box or hood design, the layout can have a major impact on the ability to establish good ventilation flow and the ability to conduct spray waste powder to the filtration system.

Specific ventilation concerns impacted by booth layout are:

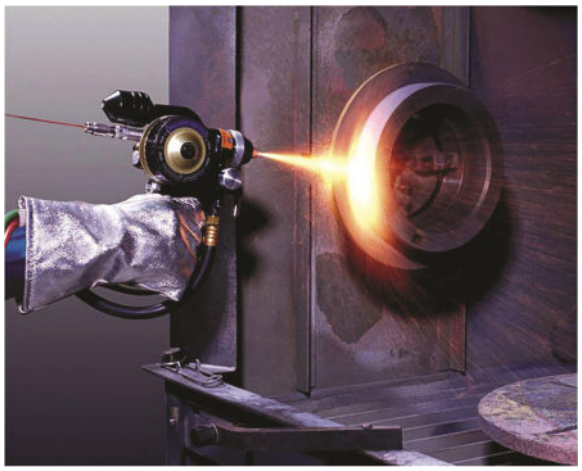
Airflow and velocities: The booth layout will affect total airflow capacity and will determine velocities. Air velocities will have a significant impact on the ability of the dust collection system to capture dust particles and carry them into the ductwork leading to the filters rather than having them settle and accumulate on the booth floor, walls and tooling. Improper or excessive airflow can affect spray patterns and flame direction.

Negative pressure: With a properly designed dust collector, the exhaust fan will create a negative pressure on the booth itself. While booth doors are closed and the system is operating, this negative pressure condition will prevent dust/air from escaping the booth.

Laminar flow: The smoothest possible flow of air helps ensure effective removal of dust from the process area, carrying it into the ducts leading to the dust collector filters. Turbulent flow may create eddies and low pressure areas that cause dust to be trapped or dropped from the air stream.

Entry timer: A timer is recommended to prevent entry into the booth until a preset time has elapsed after the shutdown of the process. The entry timer should allow enough time to clear the air of hazardous material.

When designing an exhaust system, you should evaluate each process and the output of the process intended for the spray operation. In particular, the following must be considered with the design of a dust collection system:



Combustion wire spray process

Gases: The gases used and produced vary depending on the thermal spray process. HVOF is a combustion process which uses explosive or combustible gases and oxygen. A plasma gun mainly uses inert gases but can also use hydrogen, which is an explosive gas. A dust collection system can be used to prevent the build-up of the combustible/explosive gases. Under no circumstances can the buildup of combustible products be allowed in any spray booth, as the thermal spray process itself is a guaranteed source of ignition.

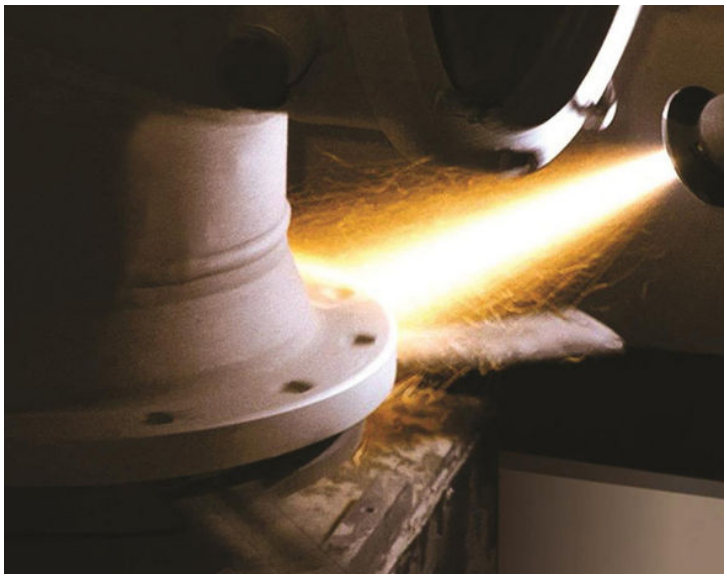
The total flow of gas should be considered in the calculations used to determine the necessary ventilation airflow as well as the booth size. The types of gases, booth dimensions, as well as the dimensions of the parts being sprayed should also be considered to determine ventilation airflow. The types and forms of materials used in the spray process and their associated hazards also vary.

The following information should be documented during the design phase:

- Materials to be sprayed and their general classifications with regard to toxicity and flammability. This information can be readily obtained from each material's MSDS.
- The allowable exposure levels must be known, to allow system design to control these levels. These include OSHA PELs, NIOSH Recommended Exposure Limits or RELs, and Threshold Limit Values or TLVs set by the American Conference of Governmental Industrial Hygienists.
- Annual consumption of each material based upon spray rates and hours of operation.
- Expected inflow of each material (overspray) into the dust collector for a given unit of operating time.
- Calculated emission of each material into the atmosphere on an annual basis, given the information above and the efficiency of the dust collection system.
- Calculated air-to-cloth ratio in the exhaust stream along with the recommended ratio for the filters and the specific thermal spray application.

If any changes are made in the process, they need to be documented and re-evaluated to allow proper safety revisions.

Reaction by-products (exothermic): The gases, materials and powders used in thermal spraying can generate various reaction by-products that must be considered in the overall design of the integrated thermal spray system. For example, water vapor can condense from the exhaust gases of a combustion process and come in contact with dust particles (e.g., aluminum dust) that have accumulated in the air handling and filtration systems. This interaction can release hydrogen gas, resulting in a potentially explosive or flammable condition.



Wire arc spray process.

Air should not be recirculated back inside the building or back into the booth. In addition, exothermic reactions can occur resulting in sufficient heat build-up to start a metal fire. Also, metal powders can form complex metallic compounds (such as hexavalent chromium or nickel carbonyl) as a result of their exposure to the high temperature of the spray process. These by-products may have risks and exposure limits that differ from the starting material. It is necessary to follow the recommendations of thermal spray equipment/consumables suppliers to alleviate potential hazards.

Heat: Thermal spray processes produce excess heat which can elevate the exhaust air temperatures. The heat in the process can be diluted by the presence of airflow inside the booth. Insufficient airflow inside a booth may result in dangerous exhaust air temperatures; and when a booth is not present and a source capture system is used, it is important to bleed in ambient air. It is recommended that air temperatures never be allowed to exceed the design specifications of the filter cartridges.

Selecting the Right Filtration

Following are some recommended approaches that relate specifically to filtration in the dust collection system:

Air-to-cloth ratios: Air-to-cloth (A/C) ratio refers to the amount of air or process gas in cubic feet per minute (cfm) entering a dust collector, divided by the square feet of filter media in the collector. A higher A/C ratio allows the use of a smaller dust collector with lower initial cost, but it will likely result in performance problems and shorter filter life. Overly high A/C ratios can also cause dust to by-pass the filters and be released into the atmosphere.

As a result, conservative A/C ratios are recommended for cartridge dust collectors in thermal spray operations. Electric arc (twin wire arc) spray generally produces a high volume of fumes, smoke and overspray. Lower A/C ratios are required in order to properly handle these conditions without blinding or plugging the filters. If filters are blinded by excessive dust and fumes produced in any thermal spray process, the air volume will decrease as well as the carrying velocity in the ductwork.

Filter media selection: Over the past decade, nano fiber filter media that combine high performance with long life have come into widespread use. Fine-pored nano fibers act as a pre-filter to the base media, capturing most of the dust at the surface before it imbeds in the filter. This technology further increases a filter's dust capture efficiency while also enhancing cleaning ability and service life.

For thermal spray applications, nano fiber media filters with a rating of MERV 15 per ASHRAE 52.2:2007 are recommended in order to meet EPA, state, and local regulations on industrial plant emissions. The media should also be flame retardant.

Pre-filtration module: Cyclones or drop-out modules can be used in addition to dry media filters to enhance cleaning efficiency by enabling the capture of larger amounts of dust entrained in the air stream before it reaches the primary dust collector. These pre-filter modules can also function as a spark arrestor by trapping large and/or hot particles that could otherwise damage the primary filters or send an ignition source into the collector.

A cyclone works by swirling the dirty air in a downward direction around the outside of a spiral path and then pulling the air straight up the middle. Large particles are forced down into a collection drum, unable to travel upward with the air. The overall efficiency of dust removal is rather low, but these devices excel at removing large amounts of particulates and can be used for product reclamation.

A drop-out module attached to the collector or positioned before the collector offers similar benefits to a cyclone. Drop-out modules tend to have a lower pressure drop and slow down the velocity of the air stream before entering the dust collector. They also can reduce the total cost of ownership of a collector by extending the life of the filter cartridges. Drop-out boxes before the collector take up minimal space and are easy to install and add on to existing modular-design dust collectors, but they must be maintained regularly.

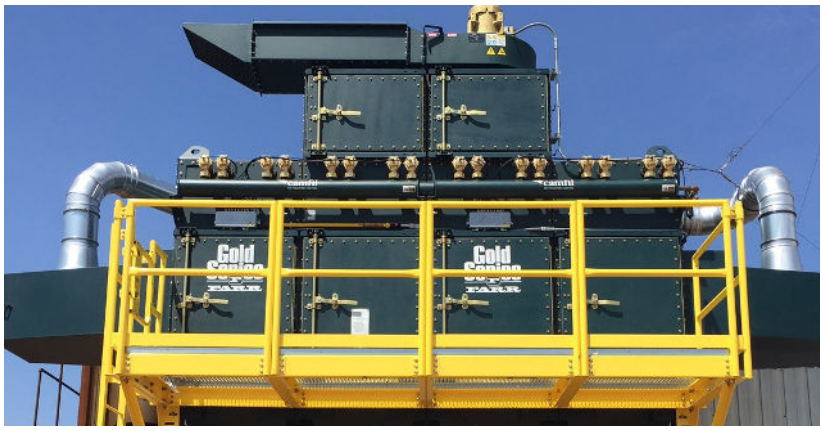
Though cyclones and drop-out boxes can extend the life of the primary filters, reduce fire risks and aid in product reclamation, they may also increase fan horsepower requirements for a subsequent trade-off in energy costs.

Secondary filter system: A secondary filter – sometimes called an after-filter, final filter or safety monitoring filter – is often recommended for use downstream of the primary filtration system; and when handling certain hazardous powders and metals such as nickel and chromium, these filters are recommended when discharging exhaust air to the atmosphere.

Traditionally, ductwork and a transition section have been required to connect this secondary filter module to the dust collection system. More recent integrated designs are available in which the safety filter is mounted on top of the collector, reducing installation costs and saving valuable floor space. This configuration also allows the filters to be located prior to the fan, thus keeping them under negative pressure. Some newer designs have also been proven through testing to function as flame arrestors for combustible dusts.

Drop-out module enhances cleaning efficiency by capturing a large quantity of dust before it reaches the primary dust collector.

Safety monitoring filters use high efficiency particulate air (HEPA) filters to enhance the dust capture efficiency of dry systems and provide backup protection if there should be an air leak through the primary filters. These units must be used in conjunction with regular dust collectors, as they are not designed to handle large volumes of particulate and fumes.



Dust collector for a twin wire arc application is equipped with secondary HEPA filters, integrated on top of the collector to enhance dust capture efficiency and provide backup protection.

Due to the gaseous by-products such as ozone, carbon monoxide and nitrous oxide generated by thermal spray processes, air recirculation downstream of the dust collector is not recommended as a general practice. However, in special circumstances, the use of a safety monitoring filter system might allow air to be recirculated through the facility to reduce heat loss and save on energy in cold climates. Also, in some instances a heat exchanger used in conjunction with a dust collector may allow safe recirculation of air on a thermal spray application. Such systems require careful design and close operational monitoring to ensure safe operation.

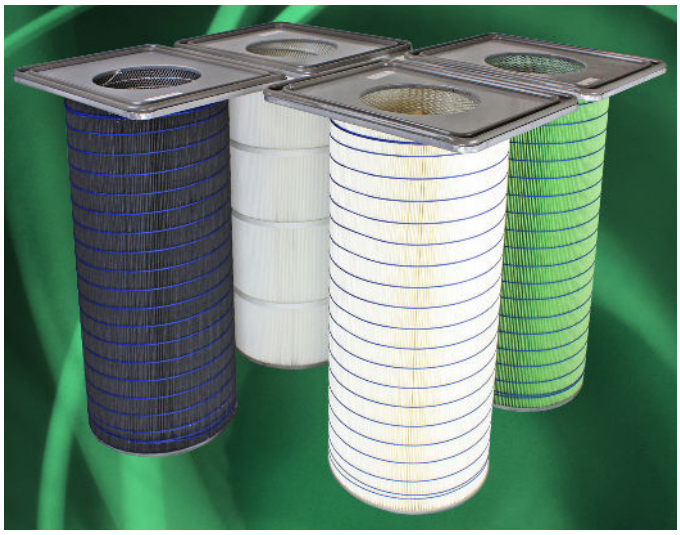
Guarantee of filter efficiency and emissions performance: There are many different methods used to measure filtration efficiency, but mass density efficiency, defined as the weight per unit volume of air, is the best predictor of a filter's compliance. The EPA, OSHA and other regulatory bodies want to know that emissions will be at or below required thresholds, typically stated as grains per cubic foot or milligrams per cubic meter.

To make sure your bases are covered, verify that the supplier will provide a written guarantee of performance stating that the dust collector filters you select will satisfy applicable emission requirements.

Explosion Protection Components

Explosion venting: Explosion vents, required for all thermal spray processes, direct the internal pressures of an explosion in the dust collection system away from workers and equipment. Explosion venting is covered in NPFA 68: Standard on Explosion Protection by Deflagration Venting.

Whenever possible, the collector should be placed outside. This allows the explosion vents to be directed away from workers and equipment. If a collector must be placed indoors, the design must allow the explosion vents to direct pressure and flame fronts safely out and away from the building and its occupants: Another alternative for indoor



Nano fiber media filters with a rating of MERV 15 per ASHRAE 52.2:2007 are recommended in order to meet thermal spray emission regulations.

installations is to use costlier explosion prevention equipment instead of venting.

Back draft damper: A mechanical back draft damper is designed for installation in the inlet ducting. The damper utilizes a mechanical barrier that is held open by the process air and is slammed shut by the pressure forces of the explosion. When closed, the mechanical barrier isolates pressure and flame fronts from being able to propagate further up the process stream – thereby protecting both the process and workers. Be sure to use a device that is compliant with NFPA 69: Standard on Explosion Prevention Systems.

Fire safety: Depending on local fire codes, a sprinkler system or other type of fire suppression system may be required. Also, to reduce fire hazards, remove combustibles from the work area and remove or isolate any ignition source not required for spraying with exhaust ventilation.

Controlling Cost Variables Associated with Dust Collection

There are three areas of cost associated with dust collection equipment:

- ***Energy*** – the amount of energy required to operate the dust collector from day to day, including electrical costs and compressed air usage.
- ***Consumables*** – the items that are replaced periodically throughout the life of the equipment.
- ***Maintenance and disposal*** – the time it takes to service the equipment and the costs of disposing of the consumables.

You can reduce the costs of these variables by engineering your dust collector properly using the methods previously outlined in this paper. As noted, choosing the correct filter and A/C ratio for your specific thermal spray application can extend filter service life, decreasing the material and labor costs associated with filter change-out and disposal and minimizing production downtime.

Another way to save energy cost is by using a premium efficiency fan motor instead of a standard efficiency fan motor in the dust collector. Still more effective is the use of a variable frequency drive (VFD). A VFD controls the fan speed to maintain the designed airflow for your application, greatly decreasing energy consumption. The use of a VFD has been proven to save an average of 4" w.g. of static pressure over the life of the filter. It can also potentially prevent filters from blinding or plugging. The added capital cost of installing a VFD on a dust collector will vary, but return on investment is typically under one year. Due to the constant flow, you also keep the quality of the coatings consistent.

Product reclamation is another cost variable that should be considered. Overspray or collected metal dust is not allowed to be thrown in the trash but must be shipped as regulated hazardous waste. When material is reclaimed, the value will be market dependent on raw material cost compounded with any potential contamination of the powder.

If the shop is spraying multiple materials, the waste generated is probably going to have less market value as it will take extra steps to separate it.

Maintenance and Housekeeping Basics

The dust collector operator should have a preventive maintenance (PM) program in place and should keep track of the differential pressure readings across the primary and secondary filters. Change-out is required when differential pressure through the system reaches the maximum level specified by the filter manufacturer. This is very important to ensure that filters are effectively controlling contaminants.

Your dust collector should be equipped with a waste storage container such as a drum or bin. This storage container must be emptied regularly, or dust can back up into the hopper. Dust sitting in a hopper can affect performance adversely by clogging up the system and preventing the automatic pulse-cleaning system from doing its job.

Where hex chrome or other toxic dust is present, clothing cannot be taken home, requiring the use of either disposable or washable clothing that remains at the workplace. Areas where the exposure exceeds the PEL are to be "demarcated from the rest of the workplace in a manner that adequately establishes and alerts employees of the boundaries of the regulated area." Access to these areas must be limited. Within the demarcated areas, "prohibited activities" include eating, drinking, smoking, chewing tobacco or gum, and the use of cosmetics.

General housekeeping practices recommended by OSHA also include the use of a shop vacuum to prevent dust from building up on floors and other surfaces before it can become airborne and/or create a slip hazard. Brushes, brooms, and compressed air systems should not be used because they will disperse dust particles into the atmosphere.

Dust collector serving a twin wire arc application uses 72 high-efficiency filter cartridges and a cyclone pre-separator that enhances cleaning efficiency and acts as a spark arrestor.

# # #

Taylor Morgan is a sales engineer for Camfil Air Pollution Control (APC). Camfil APC is a global manufacturer of dust, mist and fume collection equipment and is part of Camfil, the largest air filter manufacturer in the world. For further information, contact 1-800-479-6801 or 1-870-933-8048; email ***filterman@camfil.com****; website* ***www.camfilapc.com.***

References

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 1791 Tullie Circle, N.E. Atlanta, GA 30329; www.ashrae.org.

- ASHRAE Handbook – HVAC Systems and Equipment (2016)
- ASHRAE STANDARD 52.2: Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size (2007)

Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 1600 Clifton Rd. Atlanta, GA 30333; www.cdc.gov/niosh/: "Criteria for a Recommended Standard: Occupational Exposure to Hexavalent Chromium", DHHS (NIOSH) Publication No. 2013–128, 2013.

National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169; www.nfpa.org.

- NFPA 68: Standard on Explosion Protection by Deflagration Venting (2013)
- NFPA 69: Standard on Explosion Prevention Systems (2014)
- NFPA 484: Standard for Combustible Metals (2015)
- NFPA 652: Standard on the Fundamentals of Combustible Dust (2016)

Occupational Safety & Health Administration (OSHA), 200 Constitution Avenue, Washington, DC 20210; www.osha.gov.

- OSHA Standard on Hexavalent Chromium (OSHA Standard 3373-10), 2009
- OSHA Permissible Exposure Limits – Annotated Tables (2013)