WHITE PAPER

# How to Select the Right Dust Collection Equipment for Combustible Metal Dusts

Wet scrubbers and dry media dust collectors are two very different technologies used to capture combustible dusts generated during metalworking processes. Both types of collectors have inherent advantages and disadvantages. Which is the best type for your application? The choice is not always clear-cut, but this white paper will help with the decision process by outlining general parameters for equipment selection and NFPA compliance.

*By John Dauber, John Davidson and Mike Walters*

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# How to Select the Right Dust Collection Equipment for Combustible Metal Dusts

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Combustible dust explosions are a risk in virtually any industrial manufacturing facility whether the dust is organic or metal. However, there are few places at higher risk than facilities with processes that generate combustible metal dusts.

The metals of most concern include alkali metals, and transition metals including aluminum, magnesium, niobium, tantalum, titanium, zirconium and hafnium, of which the last five are prohibited from using dry media collectors. Metals such as carbon steel, stainless steel and mixtures of metals can also be hazardous. In a variety of industries, from aviation to sporting equipment, the use of these metals is becoming more prevalent in manufacturing processes. This paper is focused on requirements for wet and dry dust collectors as stated in *NFPA 484: Standard for Combustible Metals,* but most of the cited requirements in this document should apply to all combustible dusts.

*This dry collector uses high efficiency media filter cartridges.*

Though a big block of metal will not explode, it can become highly combustible when reduced into fine dust particles through a number of processes. According to NFPA 484, these processes include but shall not be limited to machining, sawing, grinding, buffing and polishing. Others include fettling, brushing, drilling, cutting and manual blasting.

Metal dust particles in the air in the right concentrations can create an explosion hazard, and low concentrations pose a range of environmental threats to human health, from eye and nose irritation to headaches to more serious diseases. OSHA has established permissible exposure limits (PELs) based on 8 hour time weighted average for hundreds of dusts, including a long list of metal dusts. A facility must make sure that emission levels within the plant stay below these exposure thresholds.

*This wet collector is a cylonic-type scrubber.*

Thus, plant managers and engineers are faced with a balancing act of finding the best dust collection system to capture process dusts effectively while controlling the hazards associated with combustible dusts in the safest yet also most cost-efficient manner possible. There are two basic types of dust collection systems that may be used in these situations:

## Dry dust collectors

NFPA defines dry dust collectors as cyclone and media collectors such as baghouses and cartridge collectors. This paper focuses on a comparison of high efficiency cartridge collectors and wet collectors. "Dry media" dust collectors that use or contain high efficiency filter media cartridges to capture industrial dusts are popular for a wide range of applications. Typically, dust-laden air enters the collector through a baffled inlet and is collected on the filter media. Periodic bursts of compressed air dislodge the dust from the filters and into a hopper. From the hopper, the dust is discharged into a separate storage drum or other container that must be emptied regularly to ensure that dust does not back up into the hopper. **(Figure 1)**

Some filter elements are mounted vertically while other designs mount them horizontally. Of the two types, vertical filters are recommended for several reasons. With horizontal mounting configurations, dust becomes entrained at the top of the filters, and there is no pre-separation of heavy or abrasive particles from the air stream. This situation can shorten filter life and retain large amounts of combustible dust on top of the filter that may contribute to a dust collector fire or explosion. Vertical mounting reduces the load on the filters and helps eliminate these problems, allowing more efficient pulse cleaning that extends filter service life between change-outs.

Today's cartridge dust collectors are available with a wide choice of primary filtration media that can achieve very high efficiencies on very fine particulate. Specialized media combine high efficiency with other properties like fire resistance, static conductivity and resistance to adhesive materials. In situations where materials have very low OSHA personal exposure limits (PELs), a HEPA grade secondary filter can be added to the system to achieve cleanroom grade efficiencies. This is important if the exhaust air is returned to the factory. If the secondary filter is integrated into the main filter housing, it will act as a particulate and flame retention device and provide deflagration protection to the facility. The performance of this type of control would fall under the "Performance-Based Options" in NFPA and would require third party testing to prove that it can control the hazard. Performance-Based Options are described further in the section on Process Hazard Analysis.


*Figure 1: Cutaway view of dry media-type high efficiency cartridge dust collector.*

An important development in the last decade involves the advent of nano fiber filter media for primary filters that combine high performance with long life. 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: These filters can be as high as 99.999 percent efficient on 0.5 micron and larger particles by weight. Nano fibers also enhance cleaning ability and service life. Extended filter life is always an attractive performance feature because of the obvious reductions in maintenance and replacement costs.

## Wet collectors

"Wet" dust collectors, also called wet scrubbers, operate very differently from dry media collectors. Scrubbers filter dust by impingement with water droplets. The smaller the droplet, the more efficient the scrubber. Various designs incorporate spray nozzles, misters, cyclonic action, venturi dispersion, and wet impingement configurations to capture the dust. Many devices use a combination of these techniques. Once captured, the water and dust drop into a settling tank where they are separated by gravity or the dust is skimmed from the surface.

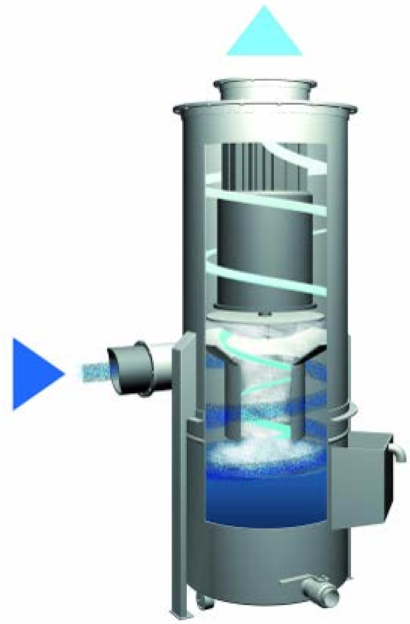

*Figure 2:*
*Cutaway view of cyclonic-type wet scrubber with integrated fan/ventilator.*

A venturi scrubber typically employs a venturi shaped constriction and spray nozzle on the inlet which accelerates the water to break it into a fine mist. The higher the velocity, the more efficient the collector becomes due to mist particles becoming finer as velocity increases. As this occurs, pressure drop through the system also increases sharply. Design airflow must be maintained constantly or the efficiency will drop.

Cyclonic or centrifugal-type scrubbers employ a variety of design techniques. In one example, dust-laden air enters tangentially and centrifugal forces move the particulate to the outer wall like a cyclone. The airflow is specially routed to generate an intensive swirl of water which mixes with the dust, causing the particulate to impinge with droplets. Once captured, the particulate will settle to the bottom of the sludge tank. Some models incorporate a fan blade in contact with the wet side of the scrubber. **(Figure 2)**

In the case of fibrous or sticky dusts, the fan is mounted on top of the collector, separating it from direct contact with the incoming dust. Fibrous and sticky dust can collect on the fan wheel and cause it to go out of balance and vibrate. By mounting on the clean side of the collector this is avoided.

If dust floats and does not settle in the hopper, special skimmers may be needed to provide clean water to maintain scrubber efficiency. In any case, maintaining a clean or recycled water supply is always an important consideration with scrubbers. The concentration of dust particles in the scrubbing fluid must be kept below five (5) percent in order to maintain operating efficiency and in the case of combustible metals, the amount allowed to accumulate in the discharge vats is prescribed in NFPA 484.

Many metals are reactive with water and produce hydrogen gas. NFPA 484 advises to test for reactivity in order to determine if a wet scrubber is appropriate. The standard also prescribes acceptable means and methods to ventilate the scrubber holding tanks.

Wet scrubber filtration efficiencies are dependent on a number of factors. The efficiencies are very dependent on the particle size of the dust being collected. If the dusts particles are less than 10 microns, a venturi scrubber should be used. The higher velocities through the venturi cause a finer mist that helps capture the smaller particles, but it also increases the energy requirements due to the high velocities going through the venturi. If the particle size is over 10 microns, the cyclonic type collector will save a significant amount of energy.

## Deciding between wet and dry systems for combustible dust collection

An important advantage of wet scrubbers is that they inherently control the combustibility of a dust. When combustible dust particles are captured into the scrubbing liquid, they are no longer in contact with oxygen, and the combustible dust hazard is controlled.

By comparison, dry media collectors are inherently at higher risk of a combustible dust explosion. As a result, they require more ancillary explosion protection equipment to meet NFPA standards. Depending on the location of the collector, the explosivity of the dust, and other factors, there is a variety of explosion prevention or control equipment to choose from. These fall into two categories: passive and active.

The goal of explosion prevention equipment is to control an explosion, keep employees safe, and minimize equipment damage in the plant. Control systems react to the pressures created during a deflagration and prevent the explosion by limiting the maximum pressures developed in the vessel and preventing the deflagration from traveling to other vessels connected to the primary vessel.

An active system involves much more costly technology and typically requires re-certification every three months. Passive devices do not require external controls and can be inspected by the owner/operator. Passive devices include explosion venting, flameless venting, flow activated flap valves, and float valves. Active devices include chemical isolation and suppression systems and fast acting valves.

**Table 1** provides a general comparison of wet and dry dust collectors and will serve as a useful tool in the equipment selection process.

Sometimes the choice between a wet vs. dry media system will not be clear-cut. Dust testing is an essential first step in the decision-making process. There are two types of dust testing: (1) lab testing, which pinpoints physical properties of the dust that affect filter efficiency and performance, and (2) explosibility testing, which determines combustible and explosive properties of the dust.

Lab testing involves a series of tests that provide valuable data for equipment selection. *Particle size analysis* reveals the dust's particle size distribution down to the submicron range to determine the filtration efficiency needed to meet emissions standards. This test pinpoints both the count (the number of particles of a given size) and the volume or mass spread of the dust. *A scanning electron microscope (SEM)* provides visual analysis of the dust shape and elemental constituents.

*Moisture analysis* equipment measures a dust's moisture percentage by weight, providing information that can prevent moisture problems. A *vaper chamber* is used to see how quickly a dust will absorb moisture. This helps to identify hygroscopic (moisture-absorbent) dust which may be more effectively captured by wet scrubbers. Additional bench tests can help to determine the optimal design of other dust collection system components.

To determine whether a dust is combustible, it should undergo separate explosibility testing as stated in *NFPA 68: Standard on Explosion Protection by Deflagration Venting.* This standard recommends testing per either ASTM E1226-12a or ISO 6184/1. If a dust sample is not available, it is permissible

## TABLE 1. COMPARISON OF WET AND DRY DUST COLLECTORS

| Application: | Wet | Dry | |
|---|---|---|---|
| Light dust loading | Yes | Yes | |
| Heavy dust loading | No | Yes | |
| Sticky dusts | Yes | No | 1 |
| Metal dusts (Kst < 150) | Yes | Yes | |
| Metal dusts (Kst > 150) | Yes | Maybe | 2 |
| Prohibited by NFPA on some dusts | No | Yes | 3 |
| Located inside without explosion protection | Yes | No | |
| High efficiency | No | Yes | |
| Energy cost | High | Lower | 4 |
| Exhaust can be recycled to plant | No | Yes | 5 |
| Exhaust to atmosphere requires EPA stack permit | Yes | Yes | |
| Requires clean water, tanks, pumps | Yes | No | |
| Continuous ventilation of waste tank/bin | Yes | No | 6 |
| Regular removal of sludge or collected dust | Yes | Yes | |
| Handling of reactive metal waste prescribed by NFPA | Yes | Yes | |
| Require explosion prevention and control devices | No | Yes | 7 |

*1. Some filter media are washable and can handle sticky materials. The application should be approved by the filter vendor.*

*2. Dry media filters have been shown to perform satisfactorily with metal dusts with Kst above 150. NFPA imposes this limit because it assumes a combustible dust incident will occur at some point with these dusts. A hazard analysis and risk assessment will help determine if a dry collector is suitable for this application.*

*3. NFPA prohibits the use of dry media collectors on niobium, tantalum, titanium, zerconium and hafnium.*

*4. Wet scrubbers require much more energy to achieve the same efficiencies as dry media collectors.*

*5. NFPA 484 prohibits recycling of the exhaust from all collectors handling combustible metals back into the plant. However, considering current technology and high efficiency secondary filtration along with flame front arresting filters, it is possible to lower the risk of returning exhaust back to a factory to acceptable levels.*

*6. Metal dusts tend to react with water to produce hydrogen gas. Many explosions have been documented and tanks on wet systems are required to be continuously ventilated.*

*7. Although wet systems don't require explosion venting as dry systems do, they are still subject to explosion hazards if the sump tanks are not ventilated, if the tanks are allowed to collect too much particulate, and/or if the tanks run dry. A more stringent monitoring and control of these systems is required compared to the passive control devices available for dry collection systems. Also, since wet systems are located inside the factory, a deflagration or explosion would produce considerably more damage and risk to life than a vented deflagration in a dry collector located outside.*

to use an equivalent dust (i.e., same particle size, etc.) in an equivalent application to determine combustibility properties. But once the dust becomes available, it is still recommended that you go back and test the dust using standardized test methods.

Using your dust sample, the lab will start with a screening test to determine whether the dust is combustible. If the dust is not combustible, testing will stop there. If it is combustible, the lab will conduct further testing on dust cloud parameters to pinpoint the Kst value and Pmax (the maximum pressure in a contained explosion). Depending on your application, you may also need to determine the minimum explosion concentration (MEC) and the minimum ignition energy (MIE).

Explosibility testing is essential to help analyze the best type of collection system (wet or dry) for an application as well as the explosion protection or prevention equipment that may be needed on the dust collector and related components.

## NFPA 484

When selecting equipment for combustible metal dust applications, *NFPA 484: Standard for Combustible Metals* is the guiding document. This standard covers all metals and alloys in a form that is capable of combustion or explosion, and it outlines procedures that shall be used to determine whether a metal is in a combustible or noncombustible form. It also applies to processing or finishing operations that produce combustible metal powder or dust such as machining, sawing, grinding, buffing and polishing.

Though a thorough analysis of NFPA 484 is outside the scope of this paper, here is a summary of key points you will need to consider.

## Process hazard analysis

Process hazard analysis (PHA) and risk assessment are tools used to improve safety by identifying hazards such as combustible dust deflagration, fire and explosion hazards. The analysis should start at the design phase of a project and follow the process to the end of its lifespan with periodic reviews and updates.

*NFPA 652: Standard on the Fundamentals of Combustible Dust* is a new standard released in October 2015. It is now the starting point for defining a combustible dust and its hazards. Its purpose is to clarify the relationship between the shared standards and the industry-specific standards such as NFPA 484. NFPA 652 introduces a new term, Dust Hazard Analysis or DHA, to differentiate this analysis from PHAs required by OSHA for the chemical process industry.

The NFPA committee recognized the widespread lack of understanding of combustible dust hazards in industry and determined that a combustible dust standard was needed to promote awareness of the problem. Most of the information/requirements in this new standard are carried over from the other standards, so users should not be surprised by any of the content. However, there is one new requirement that will affect every industry with a combustible dust hazard. For existing processes handling combustible dusts, the **"owner/operator shall schedule and complete DHAs of existing processes and facility compartments within a 3 year period from the effective date of the standard".** This effective date is October 2015. Currently OSHA cites facilities that don't have a process hazard analysis, and this new standard will increase enforcement efforts.

The type of dust collector, explosion protection and duct isolation required for each application will vary, and a PHA should be conducted to determine system requirements. Given the importance and complexity of combustible dust issues, an independent professional engineer, and/or an internal engineer knowledgeable of the process should perform the assessment with support from the dust collector and protection control suppliers. He or she can specify the best approach for your application to ensure compliance with applicable standards.

Though PHA is performed for safety reasons rather than cost control, it can contribute to cost efficiency by ensuring that safety requirements are met without over-engineering the system. In the absence of such an evaluation, the dust collection equipment supplier must default to a worst-case scenario and adhere strictly to the prescribed controls in the standards, known as the *prescriptive approach.*

The NFPA uses relatively conservative empirical and proven recommendations in its prescriptive standards for explosion protection. However, since 2008, NFPA has been incorporating something known as “performance-based options” into its updated standards. Following a *performance-based approach* as an alternative to the prescriptive methods, equipment designs will meet NFPA requirements if they satisfy the Life Safety Goals and are backed by third party testing.

In other words, the control equipment design must perform within certain test parameters that demonstrate that it will control the hazard as intended and meet the NFPA Life Safety Goals. The consumer must assure that the control equipment is installed, operated and maintained within the tested limitations of the design. The performance-based design option is a sometimes overlooked strategy.

## General considerations for dust collection - Chapter 9.4

In addition to implementing a hazard analysis, NFPA 484 includes several provisions in Chapter 9 that apply whether you are using a wet or dry collection system. Although NFPA 484 is industry-specific to combustible metals, these requirements make sense to use on any combustible dust application. **Table 2** summarizes the general requirements for the system.

| TABLE 2. NFPA 484 GENERAL CONSIDERATIONS FOR DUST COLLECTION SYSTEMS HANDLING COMBUSTIBLE METALS |
|---|
| Machines that produce dust shall have a dust collection system |
| Capture dust with a hood or let it fall into a controlled area |
| Keep ducts as straight as possible |
| Hoods and ducts should be kept free of buildup |
| Dry type dust collectors should be designed to minimize dust internally except for discharge container |
| Condensation should be prevented in any part of system |
| Condensation should be controlled with insulation and heating |
| Do not collect incompatible powders |
| **Hot Metal Particles** |
| Grinding, thermal spray and others: Locate collectors far enough away to eliminate possibility of sparks igniting filters |
| Metal temperature at filter must be below temperature limit of media |
| Do not mix grinding with buffing and polishing |
| **Ducts and Ductwork** |
| Refer to NFPA 91 |
| Use velocities designed to re-entrain dust that drops out in the event of an unscheduled shutdown |
| Dust loading should be held below MEC per NFPA 69 |
| Design ducts in a manner that minimizes interference with airflow |
| Ducts should be conductive, smooth inside, and laps should face direction of airflow |
| No dead spaces |
| Duct seams should be oriented away from people |
| Adding or removing branches requires reanalysis of the ductwork design |
| Unused sections should not be blanked off |
| Duct, collectors and machinery should be bonded and grounded |
| Use conductive jumpers when needed |
| Filter media should be static dissipative |

**TABLE 3. NFPA 484 REQUIREMENTS FOR WET SCRUBBERS**

Exhaust must be vented outside
The return of clean air is prohibited unless it meets certain efficiency requirements and does not contain combustible gases
Defines duct construction, inspection, and cleaning
Prohibits scrubbers where the dry dust contacts moving parts
Requires blower to be on the clean side of the air stream
Allows dry media after-filters if:
(1) DP alarm
(2) static dissipative media
(3) Limit hydrogen to 10% of LFL
(4) High temp alarm on dry media limit
Specifies sump ventilation volumes, timing and interlocking
Specifies interlock to process for shutdown, startup and upset conditions
Provides requirements for sludge removal, storage, inertion and disposal

**TABLE 4. NFPA 484 REQUIREMENTS FOR ALL DRY TYPE COLLECTORS (CYCLONES & MEDIA COLLECTORS)**

Located outside
Located inside if:
1. DHA shows it is an exceptable risk
2. Appropriate protections are incorporated
3. PPE is specified
4. Collector and system are static dissipative
5. Dust in collector is limited to 2.2 kg or 5 lbs

No contact between dust and moving parts allowed
Blowers located on clean side of collector
Materials of construction compatible with dust
Empty discharge containers before full
Remove dust at least daily
Remove and dispose of dust as prescribed in the standard
Clean and isolate collector before performing repairs
Protected per NFPA 68 and 69 - venting, suppression, isolation and ignition control
Specific warning signage is required
Recycling of exhaust air is prohibited[1]

[1] *Authors' note: The standard is contradictory here. It allows recycling of air from a wet scrubber when the efficiency and gas quality meets certain criteria. It is much easier to meet the criteria with a dry collector, so this prohibition is being challenged by the public.*

## Wet Scrubbers

NFPA 484 specifies requirements for wet scrubbers handling combustible metal dusts. They are summarized in **Table 3.** The main difference between metals and organic combustible dusts is the reactivity with water. Venting of the sump system is critical in controlling the buildup of combustible gases when collecting combustible metals.

## Dry Media Dust Collectors

NFPA 484 has three sections on dry collectors. The first section covers all dry-type collectors including cyclones and media collectors. The second section covers dry media collectors, and the third section covers locating dry media collectors inside. **Table 4** summarizes the common requirements for all dry media collectors.

**Table 5** (*on page 10*) summarizes additional requirements for dry media collectors. The previous table included cyclones, which explains why recirculation of air would be prohibited. The standard allows recirculation of exhaust for wet collectors if the efficiency is very high and combustible gases are not present. However, media collectors are inherently more efficient and can incorporate HEPA filters that would essentially remove all particulate; and they are dry so combustible gas buildup would only occur during an upset condition such as water ingress. This condition falls under a prescribed control, so return of exhaust air from a dry media collector could be allowed if the DHA and risk assessment are accepted by the authority having jurisdiction.

### TABLE 5. NFPA REQUIREMENTS FOR DRY MEDIA COLLECTORS

Limited to dusts with a Kst below 150[1]
Niobium, tantalum, titanium, zirconium and hafnium prohibited unless risk assessment is acceptable
Required ignition prevention measures:
1. Conductive media if MIE is less than 1 kilo joule
2. Reactivity of dust on filters with humidity in air is considered
3. System shutdown if pressure drop exceeds design threshold
4. Media replaced based on pressure drop

Spark control on spark-producing operations
Media not reactive with dust
Moisture ingress and condensation controlled to prevent hydrogen buildup
Media replacement done in a manner that avoids dust clouds

*1. Many media collectors have been successfully installed and protected on dusts with much higher Kst values. A DHA and risk assessment along with following all the recommended practices in NFPA 484 could allow higher Kst values.*

**Table 6** summarizes the requirements to locate dry-type dust collectors inside the factory. Note that this includes cyclones and the recirculation of exhaust air is prohibited again. Locating collectors handling metal dusts inside is discouraged but not prohibited. Metal fires burn extremely hot, burn for a long time and the metal can be reactive with common extinguishing agents. These properties should be considered in the risk analysis.

### TABLE 6. NFPA 484 REQUIREMENTS FOR LOCATING DRY TYPE COLLECTORS INSIDE THE FACTORY

Limited to “other metals”, i.e. metals that don’t have their own chapter in the standard
Enclosureless collectors prohibited - not efficient enough
Self-contained downdraft tables prohibited
Must meet same requirements as media collectors
DHA required
Pmax < 8 bar
Kst < 150 bar-m/s
MIE > 100 mj
Material is not UN Class 4.2 (self heating)
Collector design complies with all of this chapter
Specific signage required identifying metal type, Kst and MIE
Collection of other metals prohibited
Fire protection required suitable for the material
Collected material is not stored in collector
Isolation choke on collector discharge
Leak detection required
Exhaust duct deflagration protection - isolation or containment
Air recirculation prohibited[1]
Material is not a UN Class 4.3 solid
Water is an effective extinguishing agent
Auto cleaning (pulse jet with timer monitoring DP)
May require modifications to the emergency response plan

*1. Authors’ note: The standard is contradictory here. It allows recycling of air from a wet scrubber when the efficiency and gas quality meets certain criteria. It is much easier to meet the criteria with a dry collector, so this prohibition is being challenged by the public.*

## Working with a dust collection supplier

When selecting an equipment supplier for combustible metal dust applications, there are several important factors to consider:

*Does the supplier offer both wet and dry collection systems?* A manufacturer that offers both types of product lines is more likely to give unbiased advice on the best equipment for a given application, since they will not have a vested interested in one technology over the other.

*Will the supplier provide a written guarantee of filtration efficiency?* There are many different method used to measure filtration efficiency. Sometimes a dust collector supplier may state that a system offers 99 percent filtration efficiency at a certain particle size, or that it uses MERV 15 filters. These ratings are useful for comparing different systems, *but mass density efficiency*, defined as the weight per unit volume of air, is the best predictor of a collector's compliance. For example, OSHA might require that emissions will not exceed 5 milligrams per cubic meter at the discharge of the dust collector. Similarly, the EPA doesn't care about percentage efficiency claims: They 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 equipment you select will satisfy OSHA, EPA or other applicable emission requirements.

*How does the supplier approach NFPA compliance?* Does the dust collection supplier have broad knowledge and experience in applying NFPA standards? Also, as noted earlier, the use of performance-based codes may afford you greater latitude in equipment selection. Find out if the supplier can provide the real-world testing and documentation needed for performance-based options.

*Does the supplier have an in-house dust testing laboratory?* Many reputable suppliers will provide lab testing at no cost to customers.

*Can the supplier help evaluate total cost of ownership?* In applications where both dry and wet systems can perform effectively, equipment selection will often come down to a matter of cost. As with most purchasing decisions, initial cost of the equipment is only one factor. It requires a "Total Cost of Ownership" (TCO) evaluation to make the best equipment selection.

Similar to life-cycle costing, TCO calculates *all* the components of equipment cost: energy, consumables, and maintenance and disposal. Ask if the supplier has software to help you perform the calculations. A TCO evaluation will ultimately save you money, time and energy by ensuring the most cost-effective equipment choice.

# # #

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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; e-mail **filterman@camfil.com**, or visit **www.camfilapc.com**.

## References

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)

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