

Dust is an undesirable but inevitable byproduct of many industrial processes, particularly woodworking, paper and plastic manufacturing, food processing and metal working. It settles everywhere: in machine rooms, on roof rafters and floors, in concealed spaces and remote areas. In high concentrations, airborne dust is not only an occupational health concern for workers inhaling it, but, with the high static electricity levels and other ignition sources found in manufacturing plants and mills, also represents an ever-present risk of fire and explosion.

To reduce this hazard, dust collection systems have become part of the typical industrial setting. While they reduce free-floating dust, they create a peril of their own. Due to the concentration of dust and the heavy air flow that is essential to their operation, dust collectors can be perfect incubators for fires and explosions. Combustion requires fuel, oxygen and ignition. Collected dust is the fuel; intake fans deliver the oxygen; and machinery – sanders, grinders, dryers, milling machines – generates sparks, flames or smoldering materials that can be drawn into the collectors' air stream and provide ignition.

We devote this *Technical Advisory Bulletin* to the details of this exposure, and offer some advice on how to avoid the potentially devastating effects of the not uncommon worst-case scenarios.



A Definition

Dust is traditionally defined as material comprised of particles 420 μm in diameter or smaller (μm stands for micrometers, millionths of a meter). These particles come in three forms: blisters (liquids); typical dusts (solids produced by a mechanical process) and fumes (gases produced by a chemical process). Larger particles can also be hazardous. Comparatively flat, platelet-shaped particles, flakes or particulates of fibers with lengths that are larger than 420 μm also combust easily. Agglomerates are another problem. Many particulates build up an electrostatic charge in handling, causing them to attract each other and form agglomerates. While agglomerates often behave like larger particles, when dispersed they pose a significant hazard. In technical terms, combustible dust is defined as any particle with a surface area-to-volume ratio greater than a 420 μm diameter sphere.

The Hazards

Any time a combustible dust is processed or handled, a potential for fire and explosion exists. Laboratory tests have demonstrated that essentially all dusts (including many types of freshly created metal dusts) will burn when suspended in air or distributed on surfaces. The degree of explosion hazard potential varies, depending on the type of combustible dust and the processing methods used.

If not properly protected, dust collection systems, which collect metal, paper, plastic and wood particles at their points of origin, are susceptible to dust fires and dust explosions, which can occur both in exhaust ducts and inside dust collector housings.

Dust particles move in the ductwork in hopping motions that lead to accumulation.

Contact

For further information or guidance in this area, please contact your local Willis Property Risk Control Consultant, or Joe Stavish, P.E., North American Property Risk Control Practice Leader, at 1 800 862 1441, or joe.stavish@willis.com.

According to industry experts, some dust accumulation in a duct network is unavoidable no matter how clean or fluid it may appear. To avoid dangerous accumulations of dust and residues in the conduits, the speed of transport must be sufficient everywhere throughout the system. Fires in ducts are usually a result of poor duct design.

More than half of the losses attributed to dust fires and explosions occur in the wood and furniture industry. Most of the remaining losses are spread among the metal, food, paper, printing, chemical and textile/clothing industries.

Some Notable Dust Explosion Losses

- On June 16, 1980, an explosion and subsequent fire occurred at an aluminum grinding mill in Taito, Osaka, Japan, killing one patrolling worker and burning down three blocks of factories and a block of company houses. The cause of ignition has never been determined. Experts have speculated that the aluminum powder may have caused a dust explosion, and the fire was caused by the explosion.
- On August 20, 1997, an explosion occurred at a grain storage complex belonging to the *Société d'Exploitation Maritime Blayaise* in Blaye, France, killing 11 people. The investigation concluded that the most likely source of ignition was either a malfunctioning fan on the centralized dust collection system or auto-ignition brought about by an overheating of the dust collected coupled with a high ambient temperature.
- In 2003, a powerful explosion and fire ripped through a North American rubber-manufacturing plant, taking the lives of six employees and injuring 38 others, including two firefighters who responded to the accident. The investigation traced the explosion to combustible dust from a plastic raw material that had accumulated over the years on hidden surfaces above the production area.

The Spark

The list of possible ignition sources is alarmingly long.

- **Slow combustion** is a flameless form of combustion that takes place at low temperatures, such as a smoldering fire.
- **Spontaneous combustion** occurs when dust slowly oxidizes in a collector or in any accumulated pile. A "hotspot" develops and ignites the mixture.

- **Spontaneous chemical reactions** are caused by such processes as *polymerization* and *aluminothermy*. The former occurs in the polymer industry when parts are not completely polymerized. When these particles are milled, the heat generated can be sufficient to ignite them. In aluminothermy, a violent and exothermic reaction results when particles of aluminum interact with oxidized surface metals.
- **Electrostatic discharge** can occur wherever accumulation of a charge is possible: on the walls of non-metallic and metallic conduits; on filter bags, screens and filtration cakes of dust collector housings; in production equipment; in containers during dispensing; and in commercial ventilation ducts where air flow can cause the accumulation of static charges. According to industry experts, when a loss report concerning a dust collection system states that the cause of the loss is unknown or undetermined, it is most likely due to an electrostatic discharge; however, finding evidence of the ignition source after a loss is often very difficult.
- **Brush discharge** is a faintly visible, relatively slow crackling discharge of electricity without sparking.
- **Static spark** is a transient form of gaseous conduction, which is difficult to define, and no universally accepted definition exists. It can perhaps best be thought of as the transition between two more-or-less stable forms of gaseous conduction; i.e., the breakdown which occurs in the transition from a glow to an arc discharge. Examples include sparks generated by electrostatic discharge, brazing, welding or the normal operation of switches or contact breakers.
- **Friction** can ignite combustion when two misaligned moving surfaces are in contact and generate resistance or when components of equipment such as bearings or cogs accidentally rub against each other.
- **Electricity** is a source of accidental ignition when engines or lights generate sparks under normal operating conditions in proximity to explosive concentrations of dust or vapors.
- **Tramp materials** are unwanted items such as cigarette butts, metal parts, stones or burning debris that are drawn into the vents of an active collection system.
- **Lightning** (one megavolt of power) can cause ignition when it reaches high conducting objects that are subject to electrical discharge.

Dust Explosions in Collection Systems

Not all combustible dusts will produce explosions. For example, a coarse combustible dust such as coal may burn well, but may not explode, depending on its fineness.

A dust explosion requires four factors.

1. Combustible dust
2. Sufficient dust dispersion in air (or other oxidant)
3. Presence of an ignition source such as an electrostatic discharge, an electric current arc, a glowing ember, a hot surface, welding slag, frictional heat or flame
4. Confinement

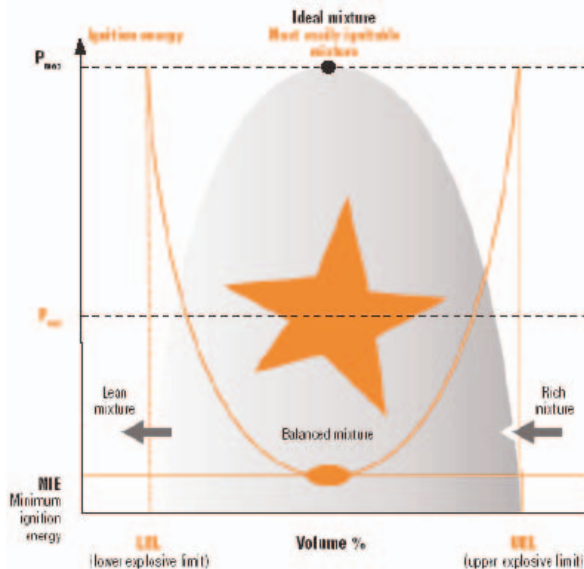
The ignition of a dust explosion depends on six factors.

1. Chemical composition of dust
2. Shape and fineness of dust
3. Dust distribution in the atmosphere
4. Concentration of oxygen in the atmosphere
5. Initial temperature and pressure of the atmosphere
6. Sufficient energy to detonate the explosion

In order for dust to sustain an explosion, its concentration must be within the material's explosive limits.

LEL (Lower Explosive Limit): Below this level of concentration, an explosion will not propagate itself. There is not enough concentration of fuel to allow the flame front to grow. A typical range of values would be 20-30 grains/ft³ (45-68 grams/m³).

UEL (Upper Explosive Limit): Above this limit, the concentration of an element is so high that there is insufficient oxygen to oxidize the fuel; the unburned fuel would stop the spread of the flame front. Only gases have UELs.



The lower explosive limit (LEL) is also referred to as the minimum explosible concentration (MEC). The MEC determines the smallest concentration of material in air that can give rise to flame propagation upon ignition when in the form of a dust cloud. No deflagration (the process of subsonic combustion that propagates through thermal conductivity) will occur as long as any dust concentration is below this limit.

Deflagration can be controlled, whereas detonation (the process of supersonic combustion in which a shock wave is propagated forward due to energy release) cannot – its speed is too fast. Detonation is much more violent and dangerous than deflagration.

Limiting Exposures: Protection Techniques

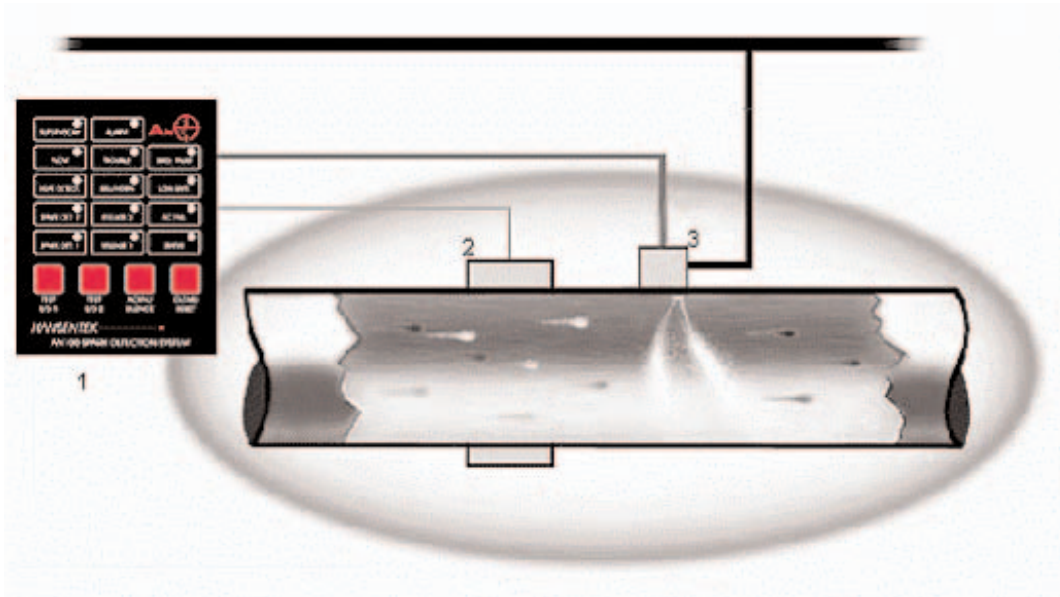
Although a facility may not be able to eliminate combustible dust from its premises, measures can be taken to reduce the frequency of dust fires and explosions. Eliminating the causes of ignition in a dust collection system can be accomplished by adopting one or all of the following approaches:

Eliminate sparks: Sparks can travel hundreds of feet in a duct. For sparks to be carried along to the collector, the flow through the duct must be laminar (smooth). Most collection ductwork is designed to operate with laminar flow to reduce pressure drop. The machinery, however, can sometimes be modified to prevent spark generation. One modification is placing a spark suppressor in the ductwork. Spark suppressors convert laminar flow into turbulent (coarse) flow for very short distances; then the flow reverts back to laminar flow. This agitation or turbulence strips the air from around the ember and cools the spark to below ignition temperature.



Spark Suppressor (Courtesy of Spark Cooler)

A more complex method of eliminating sparks is the installation of a spark detection and extinguishing system in the exhaust ductwork. When sparks enter the system through normal industrial processes or by foreign objects in the system striking metal surfaces, they are detected by sensors placed on the ductwork. A signal is sent to a control unit that triggers an extinguisher, which eliminates the spark. The control unit can also activate any user-programmed instructions to open abort dampers or shutdown machinery, and should eliminate a spark in less than 0.25 seconds. The detectors react to rapid changes in an optical field and are especially suited for viewing a cross section of a duct where the particles are visible for only a short time. Usually, two detectors are required to ensure that an entire cross section of the transport zone is fully monitored.



The three components: 1. Central Control, 2. Detectors and 3. Extinguisher (Courtesy of ExploGuard).

A spark detection system is typically used in pneumatic transport of particles (e.g., wood chips, cellulose fibers, sawdust, chemical dusts and any other combustible material) where the potential exists for combustion or explosions. Similar systems can be applied to mechanical transport systems such as conveyors or drop chutes.

Isolate operations: The collector housings should always be located outdoors or away from the main production areas. Indoor dust collectors should preferably be of the cylindrical housing type and positioned as close to a wall as possible. They should not be longer than 20 feet (6 meters).

Introduce inerting systems: Inert dust introduced into a system will eliminate the lower explosive limit of the dust mixture, resulting in a mixture that will not explode. This is especially effective where the dust concentration is very low. A comparable technique is to mix a combustible gas with another gas stream that has already oxidized, so it is not combustible.

Inert gases such as carbon dioxide (CO₂), nitrogen (N₂) and argon (Ar) can be very effective in reducing oxygen levels in dust collection systems, especially when dust collectors are located indoors. Inert gas systems are also a practical alternative to having to install deflagration vents on dust collector housings. In general, combustible organic compounds are unlikely to propagate flame if oxygen content is below eight percent.



Inert Gas Suppression Container in indoor dust collector (Photo courtesy of Fike Corporation)

Hopper fires can occur if a hopper is not cleaned out before its fan is de-energized. If a hopper door is opened, an explosion may occur. In cases where operating personnel have tried to put out a hopper fire with a hose, the water stream agitated the dust forming a dust cloud that passed through the LEL. The fire in the hopper provided a detonation source and a serious explosion occurred. In such cases, the best approach is to inject inert gas into the collector and allow it to cool below ignition temperatures before doing anything.

Fire protection or explosion suppression systems should always be interlocked with blower systems, especially if the gas stream recirculates into the building.

Use explosion vents: These can be provided on ducts and on collector housings. The vents must be directed either outdoors or to an area where an explosion can be safely dissipated. The vents can be either hinged or sheer.



Cylindrical Dust Collector (Photo Donaldson Filtration Systems)

For an indoor dust collector, explosion venting is not recommended unless a circular conduit is installed at the area of the collector housing where a deflagration is most likely to occur. This conduit should not be longer than 20 feet (6 meters) and should pass through an outside wall.

Change the design of collectors: Collectors can be reinforced to withstand higher pressures in order to make explosion venting more effective. Cylindrical collectors are more resistant to damage than rectangular collectors, but rectangular units can be braced to withstand higher explosive pressures.

According to industry specialists, non-metallic ducts or conduits should be prohibited for dust conveyance because they tend to generate static charges, even if they are sprinkler protected. The best ductwork is stainless steel, especially in corrosion-prone environments.

Be sure equipment and accessories are grounded: In the presence of combustible particles, all equipment must be grounded, including all production equipment, ventilation shafts, filters, bags, blowers and any other piece of equipment likely to accumulate electrostatic loads.



Inert Gas Suppression Container (Photo courtesy of Fike Corporation)

Grounded bags are often supplied to drain off the static electricity charge. However, grounded bags can inspire a false sense of security in operators and designers. Most often, the dust that holds a charge insulates the static charge from the containment bag. When the filter element is cleaned, sparks can be generated. Furthermore, baghouses are notoriously difficult to ground, because the metal cages carrying the filter elements often do not make proper contact with the metal frame that holds the filter bags in place. For metal-based dusts, cartridges or filter bags should be lined with copper wire in order to minimize the accumulation of electric charges.

Check grounded connections regularly.

Eliminate the chances of a secondary explosion in pulse-jet cleaning collectors: An explosion front traveling through a duct may enter the collector and dislodge the dust from the outside of the collection bags, causing a secondary explosion as the dust concentration in the housing goes over the LEL. Methods to reduce this danger include the use of smooth-finish bags where residual dust on the outside of the bags is reduced, egg-shell bag finishes and laminated TEFE bags. Static build-up can usually be reduced or eliminated by a jet cleaning system.

Off-line cleaning (in which the fan is shut down) increases the explosion hazard. If a pulse-jet collector containing hazardous dust is to be cleaned off-line, the cleaning should proceed very slowly, with perhaps three to six minutes between pulsing a single row of bags. This will diminish the chances of the dust cloud exceeding the LEL.

Minimize spontaneous combustion: Spontaneous combustion in the dust collector housings, where filter bags or cartridges are enclosed, can be prevented by jet-pulsing the collector when the system is idle.

Extinguish ensuing fire: Putting out fires can be accomplished by cooling below ignition temperature, cutting off the fuel supply or cutting off the oxygen supply.

Water sprinkler systems can be installed in collectors in the area where clean air is recycled into the work place in order to cool the particles below their ignition temperatures.

Eliminate foreign (tramp) material: Foreign materials capable of igniting combustible dusts can be removed by magnetic separators, pneumatic separators or grates.

Adopt practical loss control measures: Employees and plant supervisors can also contribute to minimizing dust accumulations by implementing several practices.

1. Minimize the accumulations of particles with a regularly implemented housekeeping program. Acceptable dust depth levels are: less than 3 mm (3/32 inch) for most general dusts and less than 0.8 mm (1/32 inch) for aluminum dusts. The most effective way to eliminate aluminum and magnesium dusts is to install a wet scrubber in the dust collector system.



Pulse-jet Cleaning Collector (Photo Courtesy of C.P.E. Filters Inc)

Dusting off particles using compressed air should be done carefully, since compressed air is a source of electrostatic energy.

2. Enforce a no-smoking policy in the work area.
3. Develop a pre-emergency plan and revise it annually or with each change of process.
4. Properly educate employees working in the presence of combustible particles; provide regular refresher courses on the hazards associated with a dust-prone environment.
5. Inspect, test and maintain safety equipment on the dust collection systems to assure that process changes do not impinge on the equipment's proper operation.
6. Implement a hot-work permit system that applies to both employees and contractors to control ignition sources such as potential sparks, flying brands or slow combustions.
7. Implement an electrical preventive maintenance program to reduce the likelihood of sparks from electrical equipment.
8. Keep records of all written reports and follow up on all interventions.

Applicable Standards and Publications

Dust collector systems must be designed, manufactured, installed and maintained in accordance with the National Fire Protection Association (NFPA) guidelines of NFPA 91-1995, "Exhaust Systems for Air Conveying Materials." FM Global utilizes its own Datasheet 7-73, "Dust Collectors and Collection Systems." Should the dust collectors be equipped with explosion deflagration venting, the design concepts should follow the guidelines of NFPA 68-1998, "Guide for Venting of Deflagrations." The NFPA 68-2002 edition should not be used since it has currently been withdrawn for revision. All other suppression or extinguishing systems used to smother or quench dust-related fire or explosion hazards should follow, preferably, the guidelines of NFPA 69-2002, "Explosion Prevention Systems," although NFPA 69-2002 is also widely accepted in the industry. FM Global has its own interpretive guideline, FM Datasheet 7-17, "Explosion Protection Systems."

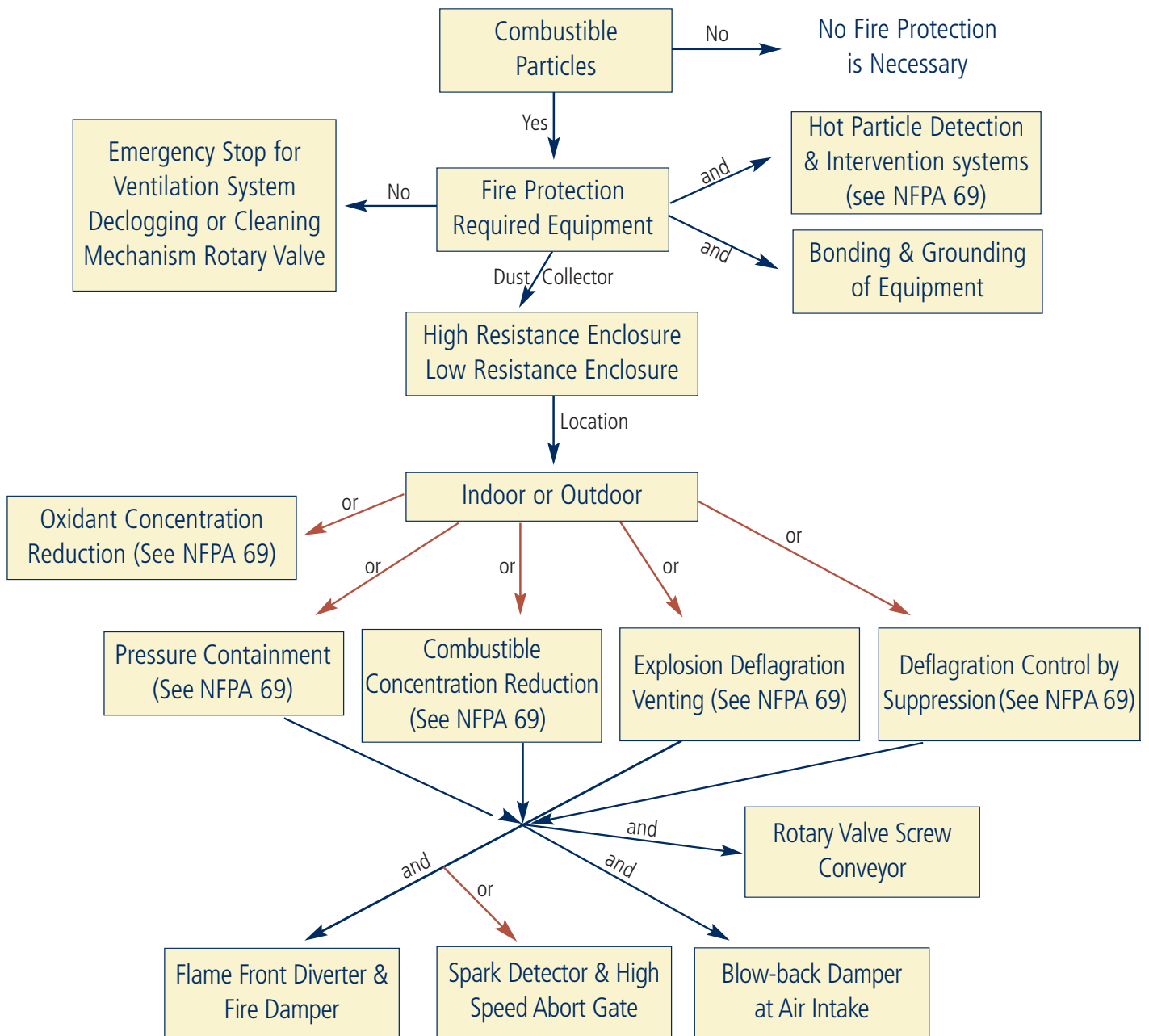
NFPA 68 was inspired by the German code VDI-3673. VDI (Veiren Deutscher Ingenieure) is an association of German engineers recognized as a leading authority for training and technological policy.



Wet Scrubber (Photo courtesy of Turbosonic Inc.)

Decision Tree for Fire and Explosions Protection

This flow chart is used by Willis Property Risk Control consulting engineers in helping clients protect their dust collection systems.



Note

1. High resistance enclosures can be of the cylindrical shape (preferably) or rectangular shape as long as their thickness <18 gauges.
2. High resistance enclosures can be installed outdoors or indoors.
3. Low resistance enclosures are of the rectangular shape with nominal thickness > 18 gauges
4. Low resistance enclosures must be installed outdoors only
5. In the field, you can distinguish a high resistance from a low resistance enclosure by the spacing between the reinforced bracings. The spacing between the reinforcements on a high resistance enclosure are 18 inches (45cm) or less. Any spacing wider than 18 inches (45 cm), the enclosure would be considered low resistance.
6. High speed abort gates are not recommended by industry experts on the air return due to their ineffectiveness in a deflagration.
7. NFPA 68 refers to the 1998 Edition, which is in turn based on the German guidelines VDI – 3673.

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Our objective is to assist management in its loss control effort. The comments and suggestions we have made are accordingly advisory. While we have endeavored to research those unsafe acts or conditions which could contribute to an accident or loss, it cannot be assumed that we have detected every loss potential or hazard, not does this report assure compliance with any federal, state or local code or law.