NFPA 650

Standard for Pneumatic Conveying Systems for Handling Combustible Particulate Solids

1998 Edition

NFPA

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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Standard for

Pneumatic Conveying Systems for Handling Combustible Particulate Solids

1998 Edition

This edition of NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Particulate Solids,* was prepared by the Technical Committee on Handling and Conveying of Dusts, Vapors, and Gases and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 17–19, 1997, in Kansas City, MO. It was issued by the Standards Council on January 16, 1998, with an effective date of February 6, 1998, and supersedes all previous editions.

This document has been submitted to ANSI for approval.

Origin and Development of NFPA 650

NFPA 650 had its origin as NFPA 66, *Standard for Pneumatic Conveying Systems for Handling Feed, Flour, Grain and Other Agricultural Dusts.* NFPA 66 was adopted as a tentative standard in 1963, and as a standard in 1964. Revised standards were adopted in 1970 and 1973.

The 1984 edition of NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials,* differed in many ways from NFPA 66. Besides differing in scope and title, NFPA 650 represented a complete rewrite of NFPA 66. The rewrite made the standard applicable to the pneumatic conveying of combustible materials, both agricultural and non-agricultural.

The 1990 edition of NFPA 650 was a reconfirmation of the 1984 edition.

For the 1998 edition, the Committee completely revised the standard to incorporate new processing and explosion protection technologies. The title of the document now reflects that the standard encompasses the conveying of all combustible particulate solids not otherwise included in previous editions of the standard. The complete revision incorporates new requirements for design basis of systems and design details for management of change.

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Committee Scope: This Committee shall have primary responsibility for documents on the prevention, control, and extinguishment of fires and explosions in the design, construction, installation, operation and maintenance of facilities and systems processing or conveying flammable or combustible dusts, gases, vapors, and mists.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

Information on referenced publications can be found in Chapter 9 and Appendix C.

Chapter 1

1-1 Scope.

1-1.1* This standard shall apply to all pneumatic conveying systems that transport combustible particulate solids, combustible dusts, or hybrid mixtures containing dusts, regardless of concentration or particle size, including systems that convey nuisance or fugitive combustible dusts.

Exception: This standard shall not apply to pneumatic conveying systems in facilities covered by NFPA 120, Standard for Coal Preparation Plants, and NFPA 8503, Standard for Pulverized Fuel Systems.

1-1.2 Additional requirements relating to specific materials or specific occupancies shall be in accordance with the following standards.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*

NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Products Facilities*

NFPA 65, *Standard for the Processing and Finishing of Aluminum*

NFPA 432, *Code for the Storage of Organic Peroxide Formulations*

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium*

NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*

NFPA 651, *Standard for the Manufacture of Aluminum Powder*

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*

NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*

1-1.3 In the event of a conflict between this standard and a specific occupancy standard, the specific occupancy standard requirements shall apply.

1-2 Purpose.

1-2.1 The purpose of this standard shall be to provide the technical requirements for pneumatic conveying systems that will provide safety to life and property from fires and deflagrations, and minimize the damage in the event that they occur.

1-3 Equivalency. Nothing in this standard shall be intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard, provided technical documentation is made available to the authority having jurisdiction to demonstrate equivalency and the system, method, or device is approved for the intended purpose.

1-4 Applicability. The provisions of this document shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion. They reflect situations and the state-of-the-art prevalent at the time the standard was issued.

Unless otherwise noted, it shall not be intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of the document, except in those cases where it is determined by the authority having jurisdiction that the existing situation involves a distinct hazard to life or property.

1-5 Definitions.

Abort Gate/Abort Damper. A device for the quick diversion of material or air to the exterior of the building or other safe location in the event of a fire.

Air-Material Separator (AMS). Any device designed to separate the conveying air from the material being conveyed. Examples include cyclones, bag filter houses, and electrostatic precipitators. The following are two types of air-material separators:

(a) *Primary Air-Material Separator.* A collector that removes the bulk of the product or material from the conveying air stream.

(b) *Secondary Air-Material Separator.* A device for removing the residual dust or product remaining in the air stream after the primary air-material separator.

Air-Moving Device (AMD).* A power-driven fan or blower that moves a volume of air in order to overcome the resistance to flow that is caused by exhaust system components.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Booster Fan. See Relay Fan.

Combustible Dust.* Any finely divided solid material 420 microns or smaller in diameter (material passing a U.S. No. 40 standard sieve) that presents a fire hazard or a deflagration hazard when dispersed and ignited in air.

Combustible Particulate Solid.* Any combustible solid material comprised of distinct particles or pieces, regardless of size, shape, or chemical composition that generates combustible dusts during handling. Combustible particulate solids include dusts, fibers, fines, chips, chunks, flakes, or mixtures of these.

Deflagration. Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium.

Detachment Area. Area located in the open air or in a separate building.

Detonation. Propagation of a combustion zone at a velocity that is greater than the speed of sound in the unreacted medium.

Duct. Pipes, tubes, or other enclosures used for the purpose of pnuematically conveying materials.

Dust Collector. See Air-Material Separator.

Explosion. The bursting or rupture of an enclosure or a container due to the development of internal pressure from a deflagration.

Fire Barrier Wall. A wall, other than a fire wall, having a fire resistance rating.

Fire Wall. A wall that has a fire resistance rating and structural stability used to separate buildings or subdivide a building to prevent the spread of fire.

Flammable Limits.* The minimum and maximum concentrations of a combustible material, in homogeneous mixture with a gaseous oxidizer, that will propagate a flame.

Hybrid Mixture.* Any combination of a combustible dust, flammable gas, or combustible mist that produces an ignitable mixture.

K_{St}.* The index of dust explosibility is defined as:

$$K_{St} = \left(\frac{dP}{dt}\right)_{max} V^{1/3}$$

where V is the volume of the test vessel. The value of $(dP/dt)_{\max}$ will be a maximum for a particular dust concentration, referred to as the "optimum" concentration, and is characteristic of the particular dust.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed.* Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

Minimum Explosible Concentration (MEC).* The minimum concentration of combustible dust suspended in air, measured in mass per unit volume, that will support a deflagration as defined by the test procedure in ASTM E 1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts.*

Noncombustible Material. A material that, in the form in which it is used and under conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Materials that are reported as passing ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C,* shall be considered noncombustible materials.

Pneumatic Conveying System. A pneumatic conveying system consists of a material feeder, an air-material separator, an enclosed ductwork system, and an air-moving device in which a combustible particulate solid is conveyed from one point to another with a stream of air or other gases. Such systems are of the following two principal types:

(a) *Positive-Pressure Conveying.* Positive pressure-type systems transport material by utilizing gas at greater than atmospheric pressure. Such systems consist of a sequence of an air-moving device, a feeder for introducing materials into the system, an air-material separator, and interconnecting ducts.

(b) *Negative-Pressure Conveying.* Negative-pressure-type systems transport material by utilizing gas at less than atmospheric pressure. These systems consist of a sequence of an air intake, a material feeder, an air-material separator, an air-moving device, and interconnecting ducts.

Relay Fan. A fan or a blower installed in-line to overcome the pressure drop due to frictional losses in the conveying stream.

Separation. The interposing of distance between the combustible particulate solid process and other operations that are in the same room.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Spark. A moving particle of solid material that emits radiant energy due either to its temperature or the process of combustion on its surface.

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Wall Protector (Shield). Noncombustible surfacing applied to a wall area for the purpose of reducing the clearance between the wall and a heat-producing appliance.

Water-Compatible.* A material that is neither reactive with water nor incompatible with water and consequently can be extinguished with a water-based extinguishing system.

Water-Incompatible.* A material that does not chemically react with water but undergoes a change of phase or state upon mixture with water that renders it permanently changed or incompatible with the remainder of the process.

Water-Reactive.* A material that chemically reacts with water producing some other compound that can represent a different set of fire protection concerns.

Chapter 2 Fundamentals of Pneumatic Conveying System Design

2-1 General. The provisions of this section shall address the overall design of all pneumatic conveying systems for combustible particulate solids.

2-1.1* Plans and specifications for new and modified systems shall be prepared by qualified engineers who are knowledgeable in the design, installation, and safe operation of pneumatic conveying systems and their associated hazards.

2-1.2 Additions of branch lines shall not be made to an existing system without redesigning the entire system. Branch lines shall not be disconnected nor shall unused portions of the system be blanked off without providing a means to maintain required and balanced airflow.

2-1.3 The rate of airflow at each hood or other pick-up point shall be designed to convey and control the material.

2-1.4 All ductwork shall be sized to provide the air volume and air velocity to keep the duct interior clean and free of residual material.

2-1.5 The design of systems handling combustible particulate solids shall be consistent with the following:

(a) The physical and chemical properties of the process materials, materials of construction, and any extinguishing agents

(b) The hazards represented, including incompatibilities

2-1.6* The design basis and design shall be documented and shall include the properties defining the hazards of the material being processed.

2-1.7 Pneumatic conveying systems removing material from operations generating flames, sparks, or hot material shall not be interconnected with pneumatic conveying systems that transport combustible particulate solids or hybrid mixtures.

2-1.8 Air-Moving Devices (Fans and Blowers).

2-1.8.1 Systems shall be designed in such a manner that combustible material does not pass through an air-moving device.

Exception No. 1: Those systems designed to operate at a combustible particulate solids or hybrid mixture concentration of less than 0.0003 oz/ft³ (0.3 gm/m³).*

Exception No. 2: Those systems operating at combustible particulate solids or hybrid mixture concentration equal to or greater than 0.0003 oz/ft³ (0.3 gm/m³) and protected in the following ways:*

(a) The use of an approved explosion prevention or isolation system to prevent the propagation of the flame front from the fan to other equipment in accordance with any of the following: 3-9.1(a), (d), or (e) and 3-9.2(c), (d), or (e).

(b) AMDs shall be designed, constructed, and installed using the following materials and methods.

1. *Spark-resistant materials*
2. *Components compatible with the material being conveyed*
3. *Bearings external to the casing*
4. *Proper clearance between the fan and casing*
5. *Belt drives external to the casing*
6. *Impellers, bearings, and shafts restrained to prevent axial or lateral shift*
7. *Detection of material build-up or overheating in the AMD housing, and interlocking to shut off the AMD*
8. *Foundations and supports for AMDs designed to withstand the vibration that can result from operation of the AMD*

2-1.9 Where a system or any part of a system operates as a positive-pressure-type system and the air-moving device discharge pressure is a gauge pressure of 15 psi (103 kPa) or greater, the system shall be designed in accordance with ASME *Boiler and Pressure Vessel Code*, Section VIII or ASME B 31.3, *Process Piping*.

2-2 Sequence of Operation. All pneumatic conveying systems shall be designed with the operating logic, sequencing, and timing outlined in 2-2.1 and 2-2.2.

2-2.1 Start-Up. Pneumatic conveying systems shall be designed so that upon start-up, the system achieves and maintains design air velocity prior to the admission of material to the system.

2-2.2 Shutdown. Pneumatic conveying systems shall be designed so that upon shutdown of the process, the system shall maintain design air velocity until material is purged from the system.

2-3 Recycled Air.

2-3.1 Systems that recycle air back into the building shall be designed to prevent both return of dust with an efficiency of 99.9 percent at 10 microns, and the transmission of energy or products of combustion from a fire or explosion to the building.

Exception: Recycling of air to the building shall not be permitted under any circumstances involving hybrid mixtures or reduced oxygen (inerted) atmospheres.

2-3.2 Protection measures for the transmission of energy shall be provided in accordance with 3-9.2 of this standard.

2-4 Inerting for the Control of Ignitability.

2-4.1 Where inerting is used to maintain the material/air mixture in a nonignitable state, the system shall be designed and operated in accordance with Chapter 2 of NFPA 69, *Standard on Explosion Prevention Systems*.

2-4.2 Where oxygen monitoring is used, it shall be installed in accordance with ISA S84.01, *Application of Safety Instrumented Systems for the Process Industries*.

2-4.3* When the chemical properties of the material being conveyed require a minimum concentration of oxygen to control pyrophoricity, that level shall be maintained.

2-5 Penetration of Fire Barriers.

2-5.1 Ducts shall not pass through a fire wall, as defined by NFPA 221, *Standard for Fire Walls and Fire Barrier Walls*.

2-5.2 If ducts pass through a fire barrier wall having a fire resistance rating of 2 hours or more, they shall meet the following criteria:

(a) Be constructed and supported so that 10 ft (3 m) of the ductwork on each side of the fire barrier can resist a 2-hour fire scenario, or be provided with an approved fire damper equivalent to the wall rating

(b) Be protected by sealing the opening around the duct with a listed or approved material of a fire resistance rating equivalent to that of the fire barrier wall

2-5.3 If ducts pass through a fire barrier wall having a fire resistance rating of less than 2 hours, they shall meet the following criteria:

(a) Be protected by sealing the opening around the duct with a listed or approved material of a fire resistance rating equivalent to that of the fire barrier wall

(b) Be permitted to pass through the wall without installation of fire dampers

2-5.4* Where ducts pass through a physical barrier erected to segregate dust deflagration hazards, physical isolation protection shall be provided to prevent propagation of deflagrations between segregated spaces.

2-6 Duct Clearances.

2-6.1* All ductwork and system components handling combustible material and operating at less than 140°F (60°C) shall have a clearance of not less than 18 in. (46 cm) from combustible construction or any combustible material.

Exception No. 1: When the ductwork system is equipped with an approved automatic extinguishing system designed for the specific hazard, the clearance shall be permitted to be reduced to 6 in. (15 cm) from combustible materials and $^1/_2$ in. (13 mm) from combustible construction.

Exception No. 2: The combustible material and any combustible construction is protected by the use of materials or products listed for protection purposes or in accordance with Table 2-6.1.

2-6.1.1 Spacers and ties for protection materials shall be of noncombustible material and shall not be used directly behind the duct.

Table 2-6.1 Reduction of Duct Clearance with Specified Forms of Protection

Form of Protection	Maximum Allowable Reduction in Clearance %	
	As Wall Protector	As Ceiling Protector
$3^1/_2$-in. (90-mm) thick masonry wall without ventilated air space	33	—
$^1/_2$-in. (13-mm) thick noncombustible insulation board over 1-in. (25-mm) glass fiber or mineral wool batts without ventilated air space	50	33
0.024 in./0.61 mm (24 gauge) sheet metal over 1-in. (25-mm) glass fiber or mineral wool batts reinforced with wire, or equivalent, on rear face with at least a 1-in. (25-mm) air gap	66	66
$3^1/_2$-in. (90-mm) thick masonry wall with at least a 1-in. (25-mm) air gap	66	—
0.024 in./0.61 mm (24 gauge) sheet metal with at least a 1-in. (25-mm) air gap	66	50
$^1/_2$-in. (13-mm) thick noncombustible insulation board with at least a 1-in. (25-mm) air gap	66	50
0.024 in./0.61 mm (24 gauge) sheet metal with ventilated air space over 0.024 in./0.61 mm (24 gauge) sheet metal with at least a 1-in. (25-mm) air gap	66	50
1-in. (25-mm) glass fiber or mineral wool batts sandwiched between two sheets 0.024 in./0.61 mm (24 gauge) sheet metal with at least a 1-in. (25-mm) air gap	66	50

Note: Clearance reduction applied to all combustible surfaces within the distance specified as required clearance with no protection in 2-6.2 and 2-6.3.

2-6.1.2 With all clearance reduction systems using a ventilated air space, air circulation shall be provided as described in 2-6.4. There shall be at least 1 in. (2.5 cm) between the wall protector and combustible walls and ceilings for clearance reduction systems using a ventilated space.

2-6.1.3 Mineral wool batts (blanket or board) shall have a minimum density of 8 lb/ft^3 (3.6 kg/m^3) and have a minimum melting point of 1500°F (816°C).

2-6.1.4 Insulation board used as a part of a clearance reduction system shall have a thermal conductivity of 1 Btu/in.·ft^2·hr·°F (0.14 W/m^2·hr·°C) or less. Insulation board shall be formed of noncombustible material.

2-6.1.5 There shall be at least 1 in. (2.5 cm) between the duct and the wall protector. In no case shall the clearance between the duct and the wall surface be reduced below that shown in Table 2-6.1.

2-6.2 Duct systems operating at elevated temperatures above 140°F (60°C) shall have clearances from combustible building construction or any combustible material of not less than 18 in. (46 cm).

2-6.3 Where clearance is reduced by using an air space between the combustible wall and the wall protector, air circulation shall be provided by one of the methods described in 2-6.3.1, 2-6.3.2 and 2-6.3.3.

2-6.3.1 Air circulation shall be permitted to be provided by leaving all edges of the wall protector open with at least a 1-in. (2.5-cm) air gap.

2-6.3.2 If the wall protector is mounted on a single flat wall away from corners, air circulation shall be permitted to be provided by one of the following:

(a) Leaving top and bottom edges open to circulation by maintaining the 1-in. (2.5-cm) air gap

(b) Leaving top and both side edges open to circulation by maintaining the 1-in. (2.5-cm) air gap

2-6.3.3 Wall protectors that cover two walls in a corner shall be permitted to be open at the top and bottom edges with at least a 1-in. (2.5-cm) air gap.

2-6.4 All clearances shall be measured from the outer surface of the combustible material to the nearest point on the outer surface of the duct, disregarding any intervening protection applied to the combustible material. Clearances shall be measured as shown in Figure 2-6.4. Clearances with protection provided shall be calculated by using the following equation.

$$B = A\left(\frac{1 - R}{100}\right)$$

where:

B = minimum allowable clearance with protection

A = required clearance with no protection

R = maximum allowed percent reduction per Table 2-6.1

A and B are in the same units of length.

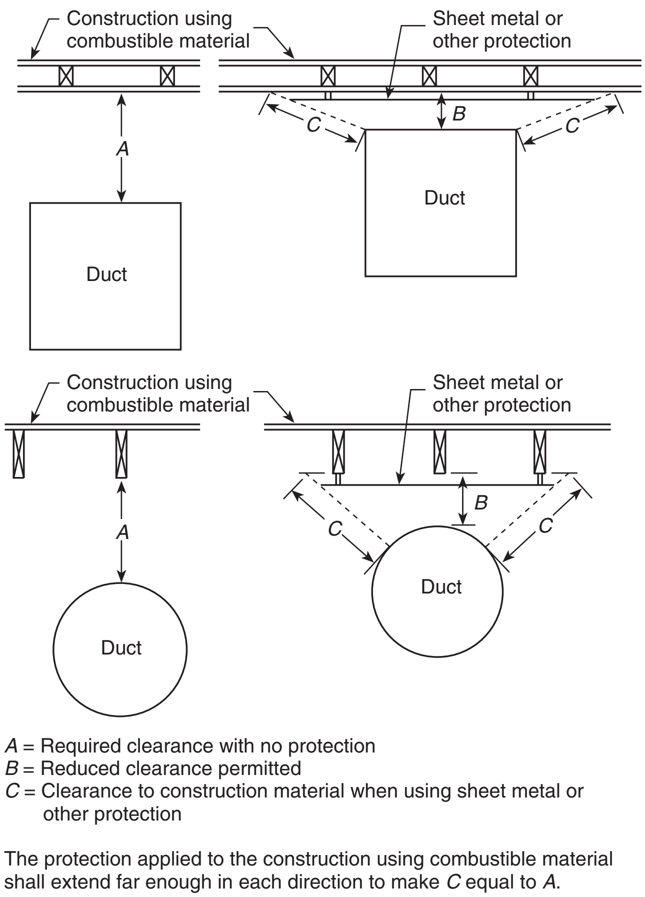


Figure 2-6.4 Extent of protection required to reduce clearances from ducts

Chapter 3 System Components

3-1 General. This chapter shall contain the construction requirements of the pneumatic system components used to construct a pneumatic conveying system, regardless of location or material transported. Subsequent sections shall contain additional requirements for specific types of combustibles or specific types of application.

3-1.1* All system components shall be conductive. Bonding and grounding with a resistance of less than 1.0×10^6 ohms to ground shall be provided.

Exception: Nonconductive equipment shall be permitted to be used when situations either (a) or (b) exist.

(a) An engineering analysis acceptable to the authority having jurisdiction has determined that no electrostatic initiation potential exists.

(b) Where materials being conveyed are not compatible with metal ductwork and other means of explosion protection are provided in accordance with 3-9.1(a), (c), (d), or (e).

3-1.2 All electrical equipment shall be designed and installed in accordance with NFPA 70, *National Electrical Code®*.

3-1.3 All components shall be designed to be airtight and dusttight.

Exception: Openings designed for intake and discharge of air and material.

3-1.4 Where more than one material is to be handled by a system, compatibility tests shall be run, and where incompatibility is found, provisions shall be made for cleaning of the system prior to transport of a new material.

3-1.5 Where the materials being conveyed are corrosive, the system shall be constructed of corrosion-resistant materials.

3-1.6 Where the atmosphere surrounding the conveying system is corrosive, the conveying system shall be constructed of corrosion-resistant materials.

3-2 Ductwork, Hoods, and Inlet Devices.

3-2.1 Ductwork handling combustible particulate solid shall be constructed as follows:

(a)* Conductive, bonded, and grounded in accordance with 3-1.1

(b) Constructed of rigid noncombustible material

Exception: Flexible hose to allow material pick-up, flexible connections for vibration isolation, and bellows for the free movement of weigh bins shall be permitted if they are conductive and the hose and equipment are bonded and grounded.

(c)* Strong enough to meet the conditions of service and installation requirements

(d) Properly protected where subject to physical damage

(e) Thoroughly braced and supported by metal hangers and brackets

(f) All lap joints made in the direction of the airflow

3-2.2 All ducts shall be made dusttight and shall have no openings other than those required for the proper operation and maintenance of the system, such as clean-out panels or service access panels for deflagration protection systems.

3-2.3 All joints and connections between components shall be butted squarely and be both airtight and dusttight. All joints shall be smooth and neatly finished.

3-2.4 Support.

3-2.4.1 All ductwork shall be supported along its length. Hangers shall be securely fastened to the structure and allow for expansion and contraction of the ductwork.

3-2.4.2 Duct supports shall be designed to carry the weight of the duct system itself, plus the anticipated weight of any conveyed materials. If sprinkler protection is provided inside the duct system, then the duct supports shall also be designed to carry the anticipated weight of any accumulation of sprinkler discharge.

3-2.4.3 Vertical runs of ductwork shall be supported at each floor level.

3-2.5 Sight Glasses.

3-2.5.1 Sight glasses shall be of a material that is impact- and erosion-resistant. Sight glass assemblies shall have a pressure rating equal to or greater than that of the ductwork.

3-2.5.2 Ductwork shall be supported on each side of the sight glass so that the sight glass does not carry any of the system weight and is not subject to stress or strain.

3-2.5.3 The mechanical strength of the sight glass mounting mechanism shall be equal to the adjoining ductwork.

3-2.5.4 The inside diameter of a sight glass shall not cause a restriction of flow.

3-2.5.5 The connections between the sight glass and the ductwork shall be squarely butted and sealed so as to be both airtight and dusttight.

3-2.5.6 The electrical bonding across the length of the sight glass shall be continuous with a resistance of no more than 1 ohm.

3-2.6* Where it is necessary to change ductwork size or shape, it shall be made with a tapered transformation piece; the included angle of the taper shall be not more than 30 degrees.

3-3 Pressure Protection Systems.

3-3.1 Vacuum breakers shall be installed on negative-pressure systems if that system is not designed for the maximum vacuum attainable.

3-3.2 Pressure relief devices for relief of pneumatic overpressure shall be installed on positive-pressure systems. For deflagration pressure relief, see 3-9.1(b).

Exception No. 1: Systems designed for less than a gauge pressure of 15 psi (104 kPa) and provided with safety interlocks designed in accordance with ISA S84.01, Application of Safety Instrumented Systems for the Process Industries.

Exception No. 2: Systems designed for less than a gauge pressure of 15 psi (104 kPa) and capable of containing the maximum pressure attainable.

3-3.3 Airflow Control Valves.

3-3.3.1 Airflow control valves installed in pneumatic systems shall be of both airtight and dusttight construction.

3-3.3.2 Airflow control valves shall be sized to allow passage of the total airflow of the system when the damper is fully open.

3-3.3.3 The position of airflow control valves shall be visually indicated.

3-3.3.4 Manually adjusted airflow control valves, dampers, gates, or orifice plates shall have a means of securing to prevent subsequent adjustment or manipulation once the system is balanced.

3-3.3.5 Diverter valves shall effect a positive diversion of the material and shall mechanically seal all other directions from air or material leakage.

3-4 Material Feeding Devices.

3-4.1 Mechanical Feeding Devices. Mechanical feeding devices shall be equipped with a shear pin or overload detection device and alarm. In those cases where a detection device and alarm are used, installation shall be in accordance with NFPA 72, *National Fire Alarm Code®*, Chapter 5.

3-4.2 Drives. All drives used in conjunction with feeders, air locks, and other material feeding devices shall be directly connected.

Exception: Belt, chain and sprocket, or other indirect drives designed to stall the driving forces without slipping and to provide for the removal of static electric charges shall be permitted to be used.

3-4.3 Foreign Materials.

3-4.3.1* Means shall be provided to prevent foreign material from entering the system when such foreign material presents an ignition hazard.

3-4.3.2 Floor sweepings shall not be returned to any machine.

3-4.3.3 Where the process is configured such that the pneumatic conveying system conveys materials that can act as an ignition source, means shall be provided to minimize the hazard. These means shall be permitted to include protection measures identified in Section 3-9.

3-5 Air-Moving Devices (AMD) (Fans and Blowers).

3-5.1 Design and Construction.

3-5.1.1 See 2-1.8.1.

3-5.1.2 Air-moving devices shall be designed, constructed, and installed per the Air Movement and Control Association, Inc. *AMCA Standards Handbook*, as applied to both ferrous and nonferrous materials. Alternate materials shall be permitted to be used only when the material is incompatible with metals.

3-5.2 Location. AMDs shall be located to permit access for inspection, lubrication, maintenance, cleaning, and repair.

3-6 Air-Material Separators (Air-Separation Devices).

3-6.1 General.

3-6.1.1 Air-material separators shall be located outside of buildings.

Exception No. 1: Those air-material separators protected in accordance with 3-9.1(a), (c), (d), or (e).

*Exception No. 2: * Those air-material separators located within 20 ft (6 m) of an exterior wall and equipped with deflagration vents, which are vented through ducts to the outside and where the reduced venting efficiency due to the duct has been accounted for. The ducts shall be designed to withstand the effects of the deflagration.*

3-6.1.2 Air-material separators shall be protected in accordance with 3-9.1.

Exception: For air-material separators located outside of buildings, a risk evaluation shall be permitted to be conducted to determine the level of explosion protection to be provided.

3-6.1.3* Isolation devices shall be provided for air-material separators in accordance with 3-9.2.

3-6.1.4 Where lightning protection is provided, it shall be installed in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems.*

3-6.1.5 Exhaust air from the final air-material separator shall be discharged outside to a personnel restricted area and away from air intakes.

Exception No. 1: Air from air-material separators shall be permitted to be recirculated directly back to the pneumatic conveying system.

Exception No. 2: Air from air-material separators shall be permitted to be returned to the building when in compliance with the requirements of 2-3.1 of this standard.

3-6.2 Construction.

3-6.2.1 Air-material separators shall be constructed of noncombustible materials.

Exception: Filter media shall be permitted to be of combustible material.

3-6.2.2 Air-material separators shall be constructed so as to minimize internal ledges or other points of dust accumulation. Hopper bottoms shall be sloped, and the discharge conveying system shall be designed to handle the maximum material flow attainable from the system.

3-6.2.3* Access doors or openings shall be provided to permit inspection, cleaning, and maintenance. Access doors or openings shall be designed to prevent dust leaks. Access doors shall be permitted to be used as deflagration vents if they are specifically designed for both purposes. Access doors shall be properly bonded and grounded.

3-7 Abort Gates/Abort Dampers.

3-7.1 Construction.

3-7.1.1 Abort gates and abort dampers shall be constructed of noncombustible materials.

3-7.1.2 The electrical continuity of the abort gate or damper releasing device shall be supervised.

3-7.2 Operation.

3-7.2.1 The abort gate/abort damper shall be installed so that it diverts airflow to a personnel restricted area.

3-7.2.2 The abort gate/abort damper shall be provided with a manual reset such that subsequent to operation it can only be returned to the closed position at the damper (gate). Automatic or remote reset provisions shall not be allowed.

3-8 Bins, Hoppers, Tanks, and Silos.

3-8.1 Bulk Storage Construction.

3-8.1.1 For the purpose of this section, bulk storage shall include such items as bins, hoppers, tanks, and silos.

3-8.1.2 Bulk storage containers, whether located inside or outside of buildings, shall be constructed of noncombustible material.

3-8.1.3 There shall be no intertank or interbin venting.

3-8.1.4* Interior surfaces shall be designed and constructed to facilitate cleaning and minimize combustible dust accumulation.

3-8.1.5* Access doors or openings shall be provided to permit inspection, cleaning, and maintenance. Access doors or openings shall be designed to prevent dust leaks. Access doors shall not be considered as deflagration venting unless specifically designed for that function. Access doors shall be properly bonded and grounded.

3-8.1.6 Fixed bulk storage containers shall be located outside of buildings.

Exception No. 1: Those fixed bulk storage containers protected in accordance with 3-9.1(a), (c), (d), or (e).

*Exception No. 2: * Those fixed bulk storage containers located within 20 ft (6 m) of an exterior wall and equipped with deflagration vents, which are vented through ducts to the outside and where the reduced venting efficiency due to the duct has been accounted for. The ducts shall be designed to withstand the effects of the deflagration.*

3-8.1.7 Fixed bulk storage containers shall be protected in accordance with 3-9.1.

Exception No. 1: For fixed bulk storage containers located outside of buildings, a risk evaluation shall be permitted to be conducted to determine the level of explosion protection to be provided.

*Exception No. 2: * Explosion protection requirements per 3-9.1 shall be permitted to be omitted, if the volume of the fixed bulk storage container is less than 8 ft^3 (0.2 m^3).*

Exception No. 3: The requirements of this section shall not apply to storage and receiving containers that are used for transportation of the material.

3-9 Fire/Explosion Protection.

3-9.1 Equipment Explosion Protection. In designing explosion protection for equipment, one of the following methods of protection shall be incorporated.

(a) Oxidant concentration reduction in accordance with NFPA 69, *Standard on Explosion Prevention Systems*

(b)* Deflagration venting directed to a personnel restricted area

(c) Deflagration pressure containment in accordance with NFPA 69, *Standard on Explosion Prevention Systems*

(d) Deflagration suppression systems in accordance with NFPA 69, *Standard on Explosion Prevention Systems*

(e)* Dilution with a noncombustible dust to render the mixture noncombustible. If this method is used, test data for specific dust and diluent combinations shall be provided and shall be acceptable to the authority having jurisdiction

3-9.2* Equipment Isolation. Isolation devices shall be provided to prevent deflagration propagation between pieces of equipment connected by ductwork. Isolation devices include, but are not limited to the following equipment:

(a)* Chokes

(b)* Rotary air locks

(c) Automatic fast-acting valve systems in accordance with NFPA 69, *Standard on Explosion Prevention Systems.*

(d) Flame front diverters in accordance with NFPA 69, *Standard on Explosion Prevention Systems.*

(e) Chemical isolation system in accordance with NFPA 69, *Standard on Explosion Prevention System.*

Exception: Isolation devices shall not be required when oxidant concentration has been reduced or when the dust has been rendered noncombustible in accordance with 3-9.1(a) or (e).

3-9.3 Equipment Fire Protection.

3-9.3.1* The fire protection system(s) associated with the pneumatic conveying system shall be specifically designed to address the conveyed material and the physical arrangement of the conveying system.

3-9.3.2* Fire Extinguishing Agents. Fire extinguishing agents shall be compatible with the conveyed materials.

3-9.3.3* Detection System Interlocks. Where fire detection systems are incorporated in pneumatic conveying systems, an analysis shall be conducted to identify safe interlocking requirements for air-moving devices and process operations.

3-9.3.4 Where fire detection systems are incorporated in the pneumatic conveying system, the fire detection systems shall be interlocked to shut down any active device feeding materials to the pneumatic conveying system upon actuation of the detection system.

Exception: Where spark detection systems are provided, the process shall be permitted to continue operating.

3-9.3.5* Where the actuation of fire extinguishing systems is achieved by means of electronic fire detection, the fire detection system, including control panels, detectors, and notification appliances, shall be designed, installed, and maintained in accordance with NFPA 72, *National Fire Alarm Code.*

3-9.3.6* All fire detection initiating devices shall be connected to the fire detection control panel via Style D circuits as described in NFPA 72, *National Fire Alarm Code.*

3-9.3.7* All fire detection notification appliances shall be connected to the fire detection control panel via Style Y circuits as described in NFPA 72, *National Fire Alarm Code.*

3-9.3.8* All fire extinguishing system releasing devices, solenoids, or actuators shall be connected to the fire detection control panel via Style Z circuits as described in NFPA 72, *National Fire Alarm Code.* The supervision shall include the continuity of the extinguishing system releasing device, whether solenoid coil, detonator (explosive device) filament, or other such device.

3-9.3.9* All supervisory devices that monitor critical elements or functions in the fire detection and extinguishing system shall be connected to the fire detection control panel via Style D circuits as described in NFPA 72, *National Fire Alarm Code.*

3-9.3.10* All fire detection abort gates or abort dampers shall be connected to the fire detection control panel via Style Z circuits as described in NFPA 72, *National Fire Alarm Code.* The supervision shall include the continuity of the abort gate or abort damper releasing device, whether solenoid coil, detonator (explosive device) filament, or other such device.

3-9.3.11 Where the actuation of extinguishing systems is achieved by means other than electronic fire detection, the system shall be designed with levels of reliability and supervision equivalent to that required in 3-9.3.5 of this standard. The extinguishing systems shall comply with the requirements of the following standards:

NFPA 11, *Standard for Low-Expansion Foam*

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*

NFPA 13, *Standard for the Installation of Sprinkler Systems*

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*

NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*

NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* as applicable, depending on the agent employed.

3-9.3.12 Sprinkler protection for pneumatic conveying systems, where required, shall be designed and installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

3-9.3.13 Special agent fire extinguishing systems, where required, shall be designed and installed in accordance with the following standards:

NFPA 11, *Standard for Low-Expansion Foam*

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*

NFPA 13, *Standard for the Installation of Sprinkler Systems*

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*

NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems*

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*

NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* as applicable, depending on the agent employed.

3-9.3.14* Spark/Ember Detection and Extinguishing Systems. Spark/ember detection systems shall be designed, installed, and maintained in accordance with NFPA 69, *Standard on Explosion Prevention Systems.*

Chapter 4 Ignition Sources

4-1 Heat from Mechanical Sparks and Friction.

4-1.1* Foreign materials, such as tramp metal, capable of igniting combustible material being processed shall be removed from the process stream using one of the following methods:

(a) Magnetic separators of the permanent or electromagnetic type; where electromagnetic separators are used, provisions shall be made to indicate the loss of power to the electromagnetic separators.

(b) Pneumatic separators

(c) Grates or other separation devices

4-1.2* Belt drives shall be designed to stall without the belt slipping, or a safety device shall be provided to shut down the equipment if slippage occurs.

4-1.3* Bearings. Roller or ball bearings shall be used on all processing and transfer equipment. Lubrication shall be performed in accordance with the manufacturer's recommendations.

Exception: Bushings shall be permitted to be used when an engineering evaluation shows that mechanical loads and speeds preclude ignition due to frictional heating.

4-1.4 Equipment. Equipment with moving parts shall be installed and maintained so that true alignment is maintained and clearance is provided to minimize friction.

4-2* Electrical Equipment. All electrical equipment and installations shall comply with NFPA 70, *National Electrical Code.*

4-3* Static Electricity.

4-3.1* For control of static electricity, see 3-1.1.

4-3.2 Where belt drives are used in the presence of combustible dusts, the belts shall be electrically conductive at 1 megohm or less.

4-3.3* The use of portable nonconductive bulk containers such as flexible intermediate bulk containers (FIBCs) shall not be permitted unless they are listed or tested by a recognized testing organization and shown not to ignite flammable atmospheres.

4-4* Powder-Actuated Tools. The requirements of 4-4.1 through 4-4.3 shall be applied retroactively.

4-4.1 Powder-actuated tools shall not be used in areas where combustible material is produced, processed, or present unless all machinery is shut down, and the area is thoroughly cleaned and inspected to ensure the removal of all accumulations of combustible material. Accepted lock-out/tag-out procedures shall be followed for the shutdown of machinery.

4-4.2 The use of powder-actuated tools shall be in accordance with Section 4-5.

4-4.3 An inspection shall be made after the work is completed to ensure that no cartridges or charges are left in the area where they can enter equipment or be accidentally discharged after operation of the dust-producing or handling machinery is resumed.

4-5 Open Flames and Sparks. The requirements of 4-5.1 through 4-5.3 shall be applied retroactively.

4-5.1 Cutting and welding shall comply with the applicable requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes.*

4-5.2 Grinding, chipping, and other operations that produce either sparks or open-flame ignition sources shall be controlled by a hotwork permit system in accordance with NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes.*

4-5.3 Smoking shall be permitted only in designated areas.

4-6 Process and Comfort Heating Systems.

4-6.1 In areas containing combustible dust, process and comfort heating shall be provided by indirect means.

4-6.2 Fired equipment shall be located outdoors, or in a separate, dustfree room or building.

4-6.3 Air for combustion shall be taken from a clean outside source.

4-6.4 Comfort air systems for processing areas containing combustible dust shall not be recirculated.

Exception: Recirculating systems shall be permitted to be used if all of the following are provided:

(a) Only fresh make-up air is heated.

(b) The return air is filtered to prevent accumulations of dust in the recirculating system.

(c) Exhaust flow is balanced with fresh air intake.

4-6.5 Comfort air shall only be permitted to flow from nonhazardous to hazardous areas.

4-7 Hot Surfaces. The temperature of surfaces external to process equipment, such as compressors, steam, water, and process piping, ducts, and process equipment, within an area containing a combustible dust shall be maintained below 80 percent of the minimum ignition temperature (in degrees Celsius) of the dust layer as determined by recognized test methods.

4-8 Industrial Trucks. In areas containing a combustible dust hazard, only industrial trucks listed or approved for the electrical classification of the area, as determined by Section 4-2, shall be used in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation.*

Chapter 5 Inspection and Maintenance

5-1 Inspection and Maintenance.

5-1.1 An inspection, testing, and maintenance program shall be implemented that ensures that the fire and explosion protection systems and related process controls and equipment perform as designed, and that a change in process equipment does not increase the hazard.

5-1.2 The inspection, testing, and maintenance program shall include the following:

(a) Fire and explosion protection and prevention equipment in accordance with the applicable NFPA standards

(b) Dust control equipment

(c) Housekeeping

(d) Potential ignition sources

(e) *Electrical, process, and mechanical equipment, including process interlocks

(f) Process changes

(g) Lubrication of bearings

5-1.3 Records shall be kept of maintenance and repairs performed in accordance with 5-1.2.

5-2 Specific Requirements.

5-2.1 Material-Feeding Devices Maintenance.

5-2.1.1 Bearings shall be lubricated and checked for excessive wear on a periodic basis.

5-2.1.2 If the material has a tendency to adhere to the feeder or housing, these components shall be cleaned periodically to maintain good balance and minimize the probability of ignition.

5-2.2 Air-Moving Devices Maintenance.

5-2.2.1 Fans and blowers shall be checked periodically for excessive heat and vibration.

5-2.2.2 Maintenance shall not be performed on fans or blowers while the unit is operating.

5-2.2.3 Bearings shall be lubricated and checked for excessive wear on a periodic basis.

5-2.2.4* If the material has a tendency to adhere to the rotor or housing, these components shall be cleaned periodically to maintain good balance and minimize the probability of ignition.

5-2.2.5* The surfaces of fan housings and other interior components shall be maintained free of rust. Aluminum paint shall not be used on interior steel surfaces.

5-2.3 Air-Material Separators Maintenance.

5-2.3.1 Air-separation devices equipped with a means to dislodge particulate from the surface of filter media shall be inspected periodically as recommended in the manufacturer's instructions for signs of wear, friction, or clogging, and these devices shall be adjusted and lubricated accordingly as recommended in the manufacturer's instructions.

5-2.3.2 Air-material separators that recycle air (i.e., cyclones and filter media dust collectors) shall be maintained to comply with 2-3.1.

5-2.3.3 Filter media shall not be replaced with an alternate type unless a thorough evaluation of the fire hazards has been performed, documented, and reviewed by management.

5-2.4 Abort Gates and Abort Dampers Maintenance. Abort gates and abort dampers shall be adjusted and lubricated as recommended in the manufacturer's instructions.

5-2.5 Fire and Explosion Protection Systems Maintenance.

5-2.5.1 All fire detection equipment monitoring systems shall be maintained in accordance with the requirements of NFPA 72, *National Fire Alarm Code.*

5-2.5.2 All fire extinguishing systems shall be maintained pursuant to the requirements established in the standard that governs the design and installation of the system.

5-2.5.3* All vents for the relief of pressure caused by deflagrations shall be maintained.

5-2.5.4 All explosion prevention systems and inerting systems shall be maintained pursuant to the requirements of NFPA 69, *Standard on Explosion Prevention Systems.*

Chapter 6 Systems for Conveying of Combustible Particulate Solids

6-1 Combustible Particulate Solids Conveying Systems Design. The design of material conveying systems transporting combustible particulate solids shall comply with the requirements of this section in addition to the requirements of Chapters 2 and 3.

6-2 Specific Requirements for Systems Conveying Metal Particulates.

6-2.1 This section shall apply to facilities that operate pneumatic conveying systems for metallic particulates.

6-2.1.1* Unless otherwise determined, metallic particulates shall be deemed water-reactive, and water-based extinguishing agents shall not be used.

Exception: Specially engineered high-density water spray systems approved by the authority having jurisdiction shall be permitted to be used.

6-2.1.2 Systems conveying alloys that exhibit fire or explosion characteristics similar to the base metal shall be provided with the same protection as systems conveying the base metal.

6-2.2 Iron, Nickel, Copper, and Other Transition Metal Particulates. The transition metal combustible particulates shall be classified as water-compatible, water-incompatible, or water-reactive based on the available chemical and physical data in conjunction with the authority having jurisdiction.

Chapter 7 Procedures and Training

7-1 Procedures and Emergency Plans. Operating and maintenance procedures and emergency plans shall be developed. These procedures and plans shall be reviewed annually, and as required by process changes.

7-2 Employee Training. Initial and refresher training shall be provided to employees involved in operating, maintaining, and supervising facilities that handle combustible particulate solids.

7-3 Content of Training. This training shall ensure that all employees are knowledgeable about the following:

(a) Hazards of their workplace
(b) General orientation including plant safety rules
(c) Process description
(d) Equipment operation, safe start-up and shutdown, and response to upset conditions
(e) The necessity for proper functioning of related fire and explosion protection systems
(f) Equipment maintenance requirements and practices
(g) Emergency response plans

Chapter 8 Housekeeping

8-1 Retroactivity Conditions. The requirements of Section 8-1 through Section 8-3 shall be applied retroactively.

8-2* Equipment Maintenance and Cleaning Frequencies. Equipment shall be maintained and operated in a manner that minimizes the escape of dust. Regular cleaning frequencies shall be established for floors and horizontal surfaces, such as ducts, pipes, hoods, ledges, and beams, to minimize dust accumulations within operating areas of the facility.

8-3* Surface Cleaning Techniques. Surfaces shall be cleaned in a manner that minimizes the generation of dust clouds. Vigorous sweeping, blowing down with steam, or compressed air produces dust clouds and shall be permitted only if the following requirements are met:

(a) Area and equipment shall be vacuumed prior to blowdown.
(b) Electrical power and other sources of ignition shall be shut down or removed from the area.
(c) Only low-pressure [a gauge pressure of 15 psi (103 kPa)] steam or compressed air shall be used.
(d) It shall be ensured that no hot surfaces exist capable of igniting a dust cloud or layer.

Chapter 9 Referenced Publications

9-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix C.

9-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 11, *Standard for Low-Expansion Foam,* 1998 edition.
NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems,* 1994 edition.
NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 1998 edition.
NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 1997 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems,* 1996 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 1996 edition.

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems,* 1995 edition.

NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems,* 1994 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 1998 edition.

NFPA 17A, *Standard for Wet Chemical Extinguishing Systems,* 1998 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials,* 1995 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes,1994 edition.*

NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Products Facilities,* 1995 edition.

NFPA 65, *Standard for the Processing and Finishing of Aluminum,* 1993 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 1997 edition.

NFPA 70, *National Electrical Code®,* 1996 edition.

NFPA 72, *National Fire Alarm Code®,* 1996 edition.

NFPA 120, *Standard for Coal Preparation Plants,* 1994 edition.

NFPA 221, *Standard for Fire Walls and Fire Barrier Walls,* 1997 edition.

NFPA 432, *Code for the Storage of Organic Peroxide Formulations,* 1997 edition.

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders,* 1993 edition.

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium,* 1995 edition.

NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium,* 1996 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation,* 1996 edition.

NFPA 651, *Standard for the Manufacture of Aluminum Powder,* 1993 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 1997 edition.

NFPA 655, *Standard for the Prevention of Sulfur Fires and Explosions,* 1993 edition.

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities,* 1993 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 1997 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 1996 edition.

NFPA 8503, *Standard for Pulverized Fuel Systems,* 1997 edition.

9-1.2 Other Publications.

9-1.2.1 AMCA Publication. Air Movement and Control Association, Inc. 30 West University Drive, Arlington Heights, IL 60004.

AMCA Standards Handbook, 99-0401-86.

9-1.2.2 ASME Publications. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME B 31.3, *Process Piping,* 1996.

ASME *Boiler and Pressure Vessel Code,* Section VIII, 1995.

9-1.2.3 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C,* 1996.

ASTM E 1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts,* 1993.

9-1.2.4 ISA Publication. International Society for Measurement and Control, P.O. Box 12277, Research Triangle Park, NC 27709.

ISA S84.01, *Application of Safety Instrumented Systems for the Process Industries,* 1996.

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-1-1.1 Pneumatic conveying addresses the broad spectrum of operations ranging from bulk conveying of process materials to systems intended to remove small quantities of airborne dusts from the workspace. Examples of industries that pneumatically convey combustible particulate solids, either as a process material or as a fugitive or nuisance dust, include but are not limited to the following:

(a) Agricultural, chemical, and food commodities
(b) Flyings, fibers, and textile materials
(c) Forest and furniture products industries
(d) Metals processing
(e) Paper products
(f) Pharmaceuticals
(g) Resource recovery operations (e.g., tires, municipal solid waste, metal, paper, or plastic recycling operations)
(h) Wood, metal, or plastic fabricators

A-1-5 Air-Moving Device (AMD). An air-moving device (AMD) is a fan, centrifugal fan, or mixed flow fan. These devices have previously been called blowers or exhausters.

A-1-5 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-5 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-5 Combustible Dust. Any time a combustible dust is processed or handled, a potential for deflagration exists. The degree of deflagration hazard will vary depending on the type of combustible dust and processing methods used.

A dust explosion has four requirements:

(a) A combustible dust

(b) A dust dispersion in air or oxygen at or exceeding the minimum combustible concentration

(c) An ignition source such as an electrostatic discharge, an electric current arc, a glowing ember, a hot surface, welding slag, frictional heat, or a flame

(d) Confinement

Evaluation of the hazard of a combustible dust should be determined by the means of actual test data. The following list represents factors that can be considered when determining the deflagration hazard of a dust:

(a) Minimum dust concentration to ignite

(b) Minimum energy required for ignition (joules)

(c) Particle size distribution

(d) Moisture content as received and dried

(e) Deflagration index (K_{St})

(f) Layer ignition temperature

(g) Maximum explosion pressure, at optimum concentration

(h) Electrical volume resistivity measurement

(i) Dust cloud ignition temperature

(j) Maximum permissible oxygen concentration (MOC) to prevent deflagration

A-1-5 Combustible Particulate Solid. A definition of this breadth is necessary because it is crucial to address the fact that there is attrition of the material as it is conveyed. Pieces and particles rub against each other and collide with the walls of the duct as they travel through the system. This breaks the material down and produces a mixture of pieces and much finer particles, called "dusts." Consequently, we should expect every conveying system to produce dusts as an inherent by-product of the conveying process, regardless of the starting size of the material.

A-1-5 Flammable Limits. For every combustible material that can be suspended or dissolved in air, either as a vapor or a dust, there is a range of concentrations within which a flame will propagate. The term "flammable limits" is usually applied to gases and vapors. For flammable gases and vapors the lower flammable limit, LFL (the minimum concentration in mass per unit volume) and the upper flammable limit, UFL (the maximum concentration in mass per unit volume) are well known.

The term "flammable limits" is not often applied to combustible dusts. Terms such as minimum explosible concentration appear in the references. Regardless of what term is used, there are limits on the concentration of dust in air that will sustain a flame. For combustible dusts, the lower flammable limit is dependent on a number of factors including particulate size, chemistry, moisture content, shape, and the concentration of the particulate in air suspension. Consequently, these factors should be defined before the lower flammable limit (LFL) can have much meaning. There is insufficient evidence at this time to postulate the existence of an upper flammable limit (UFL) for a combustible dust.

A-1-5 Hybrid Mixture. The presence of flammable gases and vapors, even at concentrations less than the lower flammable limit (LFL) of the flammable gases and vapors, will add to the violence of a dust-air combustion.

The resulting dust–vapor mixture is called a "hybrid mixture" and is discussed in NFPA 68, *Guide for Venting of Deflagrations.* In certain circumstances, hybrid mixtures can be deflagrable, even if the dust is below the LFL. Further, dusts determined to be nonignitable by weak ignition sources can sometimes be ignited when part of a hybrid mixture.

A-1-5 K_{St}. This term is discussed in more detail in NFPA 68, *Guide for Venting of Deflagrations.*

A-1-5 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-5 Minimum Explosible Concentration (MEC). This is equivalent to the term lower flammable limit (LFL) for flammable gases. Since it has been customary to limit the use of the term lower flammable limit to flammable vapors and gases, an alternative term is necessary for combustible dusts.

The minimum explosible concentration (MEC) is dependent on many factors including particulate size distribution, chemistry, moisture content, and shape. Consequently, designers and operators of processes handling combustible particulate solids should consider these factors when applying existing MEC data. Often, the necessary MEC data can only be obtained by testing.

The ability of a combustible dust to support a deflagration, and hence the MEC, is dependent on many factors including particulate size, chemistry, moisture content, shape, and the concentration of the particulate in air suspension. Consequently, these factors should be defined before the MEC can have much meaning. Unfortunately, much of the information has yet to be developed for all of the currently processed combustible particulate solids and all of the variables operative in determining the MEC. The designer and operator of pneumatic systems conveying combustible particulate solids should research the combustible particulate solid in question thoroughly to obtain the best estimate possible of the MEC.

A-1-5 Water-Compatible. These materials include many of the cellulosics such as wood waste, paper dust, textile fibers, bulk agricultural products, municipal solid waste (MSW), refuse-derived fuel (RDF), and other organic materials including coal and some plastic resins. Water spray extinguishment can be used for these materials when they are handled in systems where the process equipment is also water-compatible.

A-1-5 Water-Incompatible. Water-incompatible materials are typified by those that dissolve in water or form mixtures with water that are no longer processable, for example, sugar. While water is an effective extinguishing agent for sugar fires, the sugar dissolves into the water, resulting in a syrup that can no longer be processed pneumatically. A similar situation exists with flour; when mixed with water, it becomes dough. These materials are candidates for extinguishing systems that use media other than water until the damage potential of the fire approaches the replacement cost of the process equipment. Then water is used to protect the structure.

A-1-5 Water-Reactive. Water-reactive materials represent a very special fire protection problem. The application of water from fixed water-based extinguishing systems or by the fire service without awareness of the presence of these materials might seriously exacerbate the threat to human life or property. For example, many chemicals form strong acids or bases when mixed with water introducing a chemical burn hazard. Additionally, most metals in the powdered state can burn with sufficient heat to chemically reduce water yielding hydrogen, which can then support a deflagration.

These types of materials should be handled very carefully. Small quantities of water usually make matters worse.

A-2-1.1 The design of the pneumatic conveying system should be coordinated with the architectural and structural designs. The plans and specifications should include a list of all equipment, specifying the manufacturer and type number, and should include information as shown in (a) through (h). Plans should be drawn to an indicated scale and show all essential details as to location, construction, ventilation ductwork, volume of outside air at standard temperature and pressure that is introduced for safety ventilation, and control wiring diagrams.

(a) Name of owner and occupant

(b) Location, including street address

(c) Point of compass

(d) Ceiling construction

(e) Full height cross section

(f) Location of fire walls

(g) Location of partitions

(h) Materials of construction

A-2-1.6 The design basis generally includes, but is not limited to, the general scope of work, design criteria, process description, material flow diagrams, basis for deflagration protection, basis for fire protection systems, and the physical and chemical properties of the process materials.

The design generally includes, but is not limited to, equipment layouts, detailed mechanical drawings, specifications, supporting engineering calculations, and process instrumentation diagrams.

A-2-1.8.1 Exception No. 1. Some systems are designed to operate at solids concentrations that pose no fire or deflagration risk. Such systems include nuisance dust exhaust systems and the downstream side of the last air-material separator in the pneumatic conveying system.

A threshold concentration limit of 1 percent of the MEC has been conservatively set to discriminate between such systems and other systems designed to operate at a significant combustible solid loading. This limit ensures that normal variations in processing conditions will not result in the combustible particulate or hybrid mixture concentration approaching the MEC.

Where significant departures from normal conditions, such as equipment failure, could result in a combustible concentration approaching, or exceeding, the MEC, additional protection should be considered where the risk is significant. Such protection might include one of the following:

(a) Secondary filtration (e.g., high-efficiency cartridge filter) between the last air-material separator and the AMD

(b) Bag filter failure detection interlocked to shut down the AMD

(c) Design of the AMD in accordance with 2-1.8.1 Exception No. 2 (b), provisions (1) through (6)

A-2-1.8.1 Exception No. 2. These systems include pneumatic conveying systems requiring relay (booster) fans and product dryers where the fan is an integral part of the dryer.

A-2-4.3 The maximum allowable concentration of oxygen is very dependent on the material, its chemical composition, and, in the case of particulate solids, the particle sizes. In addition, with many combustible metals it is not advisable to completely eliminate oxygen from the transport gas. During transport, particles are abraded and broken exposing unoxidized metal (virgin metal) to the transport gas. When this metal is finally exposed to oxygen containing air, the rapid oxidation of this virgin metal might produce sufficient heat to ignite the material. It is, therefore, preferable to provide for a low concentration of oxygen in the transport gas stream to ensure the oxidation of virgin metal as it is exposed during the course of transport.

A-2-5.4 Isolation devices in accordance with 3-9.2 are provided to prevent deflagration propagation between connected equipment. In 2-5.4, additional protection is indicated when the integrity of a physical barrier might be breached through failure of the ductwork caused by a deflagration outside the equipment. In some cases, a single equipment isolation device can protect both scenarios, if that isolation device is installed at the physical barrier. In other cases, this concern can be addressed by strengthening the duct and supports to preclude failure.

A-2-6.1 Even systems operating at ambient temperatures can be a hazard to nearby combustibles if the material being transported is ignited and burned within the duct.

A-3-1.1 See NFPA 77, *Recommended Practice on Static Electricity.*

A-3-2.1(a) NFPA 77, *Recommended Practice on Static Electricity,* contains information on bonding and grounding.

A-3-2.1(c) The duct construction should conform to the following applicable SMACNA standards:

(a) *Accepted Industry Practice for Industrial Duct Construction*

(b) *Rectangular Industrial Duct Construction Standards*

(c) *Round Industrial Duct Construction Standards*

(d) *Thermoplastic Duct (PVC) Construction Manual*

Exception: Reinforced thermoset-type materials should conform to ASTM C 582, Standard Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment.

Ductwork of circular cross section is preferred over rectangular ductwork because of its inherently higher strength and the absence of corners where material will accumulate. When used, rectangular ductwork should be as square as possible.

A-3-2.6 Whenever there is a change in the size of the duct there is a change in the cross-sectional area. This change in area causes a change in air velocity in the region of the change, and this introduces turbulence effects. The net result is that a transition with an included angle of more than 30 degrees represents a choke when the direction of flow is from large to small resulting in localized heating and static electric charge accumulation. When the transition is from small to large, the air velocity drop at the transition is usually enough to cause product accumulation at the transition, and the existence of a volume where the concentration of combustible is above the MEC. It is strongly desirable to avoid both of these situations.

A-3-4.3.1 Means by which this requirement can be satisfied include magnetic, pneumatic, and screen separators. Provisions should be made for loss of power to electromagnetic separators. *[See Figure A-3-9.2(a) and Figure A-3-9.2(b).]*

A-3-6.1.1 Exception No. 2. Where explosion venting is used, its design should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations.* For explosion relief venting through ducts, consideration should be given to the reduction in explosion venting efficiency caused by the ducts. The ducts should be designed with a cross-sectional area at least as large as the vent. They should be structurally as strong as the air-material separator and should be limited in length to 20 ft (6 m). Since any bends will cause increases in the pressure developed during venting, vent ducts should be as straight as possible. If bends are unavoidable, they should be as shallow angled (i.e., have as long a radius) as is practicable.

A-3-6.1.3 For design requirements for fast-acting dampers and valves, flame front diverters, and flame front extinguishing systems, see NFPA 69, *Standard on Explosion Prevention Systems.*

A-3-6.2.3 For information on designing deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations.*

A-3-8.1.4 Horizontal projections can have the tops sharply sloped to minimize the deposit of dust thereon. Efforts should be made to minimize the amount of surfaces where dust can accumulate.

A-3-8.1.5 For information on designing deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations.*

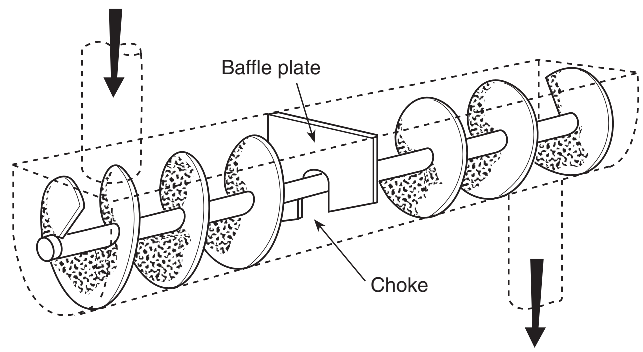
A-3-8.1.6 Exception No. 2 Where explosion venting is used, its design should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations.* For explosion relief venting through ducts, consideration should be given to the reduction in explosion venting efficiency caused by the ducts. The ducts should be designed with a cross-sectional area at least as large as the vent. They should be structurally as strong as the fixed bulk storage container and should be limited in length to 20 ft (6 m). Since any bends will cause increases in the pressure developed during venting, vent ducts should be as straight as possible. If bends are unavoidable, they should be as shallow angled (i.e., have as long a radius) as is practicable.

A-3-8.1.7 Exception No. 2. Small portable collectors can pose an explosion hazard; however, explosion protection measures for these units is not always practical. Consideration should be given to explosion hazards when electing to use these devices. For information on deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations.*

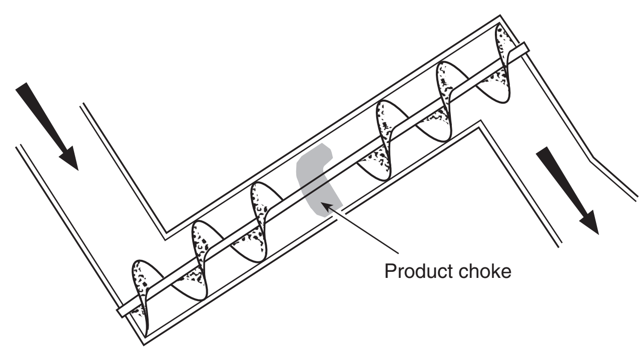
A-3-9.1(b) Where explosion venting is used, its design should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations.* For explosion relief venting through ducts, consideration should be given to the reduction in explosion venting efficiency caused by the ducts. The ducts should be designed with a cross-sectional area at least as large as the vent. They should be structurally as strong as the equipment being protected and should be limited in length to 20 ft (6 m). Since any bends will cause increases in the pressure developed during venting, vent ducts should be as straight as possible. If bends are unavoidable, they should be as shallow angled (i.e., have as long a radius) as is practicable.

A-3-9.1(e) This method is limited in effectiveness due to the high concentrations of inert material required and the potential for separation during handling. Other methods are preferred.

A-3-9.2(a) The following diagrams illustrate two different choke designs.



Example 1



Example 2

Figure A-3-9.2(a) Screw conveyor chokes.

A-3-9.2(b) The following conditions should be adhered to when using an air lock as an explosion isolation device.

(a) The angle between adjacent vanes and the shape of the housing should engage two vanes per side at all times

(b) The vanes (including the tips) should be made of metal and have a thickness of at least $^1/_8$ in. 3mm).

(c) The gap between the tips of the vanes and the housing ranges should be between 0.2mm to 0.25mm (0.008 in. to 0.010 in.) [$\leq$ 0.1 mm (0.004 in.) for aluminum dust].[1]

(d) The rotary air lock should be interlocked to automatically stop in the event of an explosion to prevent the passing of burning material. An interlock would not be needed if burning material would not cause a secondary fire or explosion of any significance.[2]

When rotary air locks are installed in both the inlet and outlet of equipment, care should be taken to ensure that the rotary air locks on the inlet are stopped before the unit becomes overfilled. See Figure A-3-9.2(b).

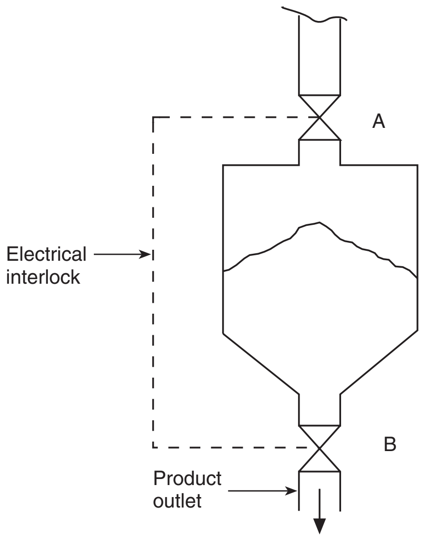


Figure A-3-9.2(b) Rotary valves.

A-3-9.3.1 There are three fire scenarios that should be addressed. The first is a fire sustained by a combustible duct. The second is a fire sustained by material adhering to the duct interior. The third is a fire involving the combustible particulate solid as it moves through the ductwork under normal operation conditions.

In the first and second scenarios, where the duct is a significant portion of the fire load or where significant quantities of combustible material have accumulated on the duct interior, fire detection and extinguishment systems for the ducts should be considered. In these cases, heat detectors and a deluge system or a sprinkler system would be applicable. This requires a means of keeping conveyed material off the detectors and discharge nozzles. It also means that it is necessary to protect the detectors and discharge heads from abrasive erosion by the conveyed material.

In the third scenario, when the combustible solids are moving, a fire could move past a heat detector so quickly that it is not detected. Spark detection and suppression systems or other high-speed extinguishing systems should be considered for ductwork or air-material separators. For protection of air-material separators and other equipment, see Section 3-6.

A-3-9.3.2 Pneumatic conveying systems that move combustible particulate solids can be classified as water-compatible, water-incompatible, or water-reactive. Inasmuch as water is universally the most effective, most available, and most economical extinguishing medium, it is helpful to categorize combustible particulate solids in relation to the applicability of water as the agent of choice.

Water-compatible particulate solids are those combustibles that can be extinguished with water and neither react with nor form mixtures with it. These include the following:

(a) Wood dusts, fibers, chips, shavings, and flakes
(b) Some paper dusts depending on ultimate use
(c) Municipal solid wastes (MSW) including refuse-derived fuels (RDF)
(d) Coal chunks, pellets, and dusts
(e) Shredded plastic and papers at recycling facilities
(f) Many plastic powders and pellets
(g) Pulverized cork in a flooring products manufacturing process
(h) Conveyed agricultural commodities such as oilseeds, walnut shells, and cocoa beans in a de-shelling operation
(i) Chopped feathers in a dryer

The chemical and physical properties, range of particle sizes, and types of process equipment used with these combustibles usually allow these applications to be considered water-compatible. A principal concern is the ignition of a dust cloud in the air-material separator or storage vessel. When the source of ignition is generated upstream, this risk can often be reduced if the spark or ember is detected and extinguished prior to its entry into the air-material separator or storage vessel. In some applications, spark detection and intermittent water spray extinguishing systems can be effectively used because the ultimate usefulness of the particulate material is not affected if it is wet.

There are numerous drying, chopping, crushing, and grinding operations where the introduction of water does not represent a serious threat to the transported material or the process equipment. For example, in woodworking plants the wood waste is usually sold as raw material for particleboard or used as fuel to heat the facility. The moisture from the operation of an extinguishing system is of no consequence. This allows the use of spark detection and intermittent water spray as the fire protection strategy. There are other applications where it is more appropriate to use water deluge systems as the fire protection strategy, even though this might disrupt the normal flow of material or interrupt the process operation.

In contrast, water-incompatible systems are those where the introduction of water will cause unacceptable damage to the equipment or the material being processed. Water-incompatible particulate solids are combustibles that can be extinguished with water but dissolve in or form a mixture with water that renders them no longer processable or where the process equipment cannot tolerate the introduction of water. These include the following:

(a) Cotton fibers (due to the resultant equipment damage from water discharge)
(b) Many foodstuffs, such as sugar, flour, spices, cornstarch, yeasts
(c) Grains and cereals
(d) Tobacco
(e) Many pharmaceuticals
(f) Many chemicals

Since the conveyed material or the process equipment is irreparably degraded when water is added to these systems, the first line of defense is an extinguishing system that utilizes some other agent. Examples of agents used in these systems include carbon dioxide, sodium bicarbonate, monoammonium phosphate, nitrogen, and clean agents. However, a water-based extinguishing system can be employed as a backup to the special agent extinguishing systems.

Examples include water soluble materials and flour. A notable example is flour. A spray of water into a pneumatic conveying duct transporting flour will extinguish a spark, but the water will combine with the flour to form paste that will clog the system and, additionally, it will promote fermentation. Consequently, there is an operations-based incentive to consider alternatives to water-based extinguishing systems.

Water-reactive materials chemically react with water to produce some other material that might represent a different set of fire protection problems. The most notable are the powdered metals. Many powdered metals including aluminum, magnesium, titanium, zirconium, and lithium react violently with water to form an oxide, liberating hydrogen gas as a by-product. These materials can start a fire when exposed to water if they are of a sufficiently small particle size. Consequently, water is not usually an option as an extinguishing agent for an established fire involving these materials.

Other metals react less violently with water and react only under certain circumstances. The use of water on these materials once they have achieved ignition temperature can also produce hydrogen. However, if used in copious quantities, water can be an effective extinguishing strategy. Nevertheless, all metals should be approached with care, as their reactivity is very dependent on the particular metal, particle size, and temperature.

The list of water-reactive combustibles is not limited to combustible metals, but includes some pharmaceuticals and chemicals. These chemicals either produce a fire, or produce a toxic or corrosive by-product when they are mixed with water.

Handling the material in an inerted system is a method often used because of the difficulties encountered in extinguishing these materials. However, it should be noted that some common inerting agents such as carbon dioxide or nitrogen might be incompatible with certain metals at high temperatures.

In summary, the classification of a combustible particulate solid should be made after a thorough review of the chemistry and physical form of the particulate, the type of process equipment, the subsequent use or processes involved, the relevant literature regarding loss history in similar processes and products, other hazards associated with the process material, and the response capabilities of the fire service.

A-3-9.3.3 The preferred interlocking requirements for the AMD and process operations should be determined on a case-by-case basis, considering the nature of the operation and of the protection systems. Factors to be considered include, but are not limited to the following:

(a) For AMDs, concerns include the potential for solids dislodging from the filter bags in air-material separators and causing an explosion when the airflow is stopped. This should be balanced against the possibility of continued air movement spreading the fire or explosion throughout the process. For example, where the discharge of the air-material separator can be diverted to a safe location, continued airflow to mitigate the explosion potential might be preferred.

(b) Regarding process operations, in some industries, spark detection and intermittent water spray systems are used to prevent fires and explosions inside transfer ducts, with the intent of quenching isolated sparks and permitting continued process operations. Administrative controls might require the shutdown of operations when sustained fires are detected. In other applications, where fire detection and suppression are provided, a more appropriate option might be to shut down process operations in order to stop the addition of fuel or combustion air to the system.

If airflow in the system is shut off, material is likely to fall off the interior of the air-material separator and increase the probability of an explosion.

This permits the stopping of airflow when it is necessary to prevent the dissipation of the extinguishing agent used.

A-3-9.3.5 NFPA 72, *National Fire Alarm Code,* provides performance criteria for fire detection and protective signaling systems. The development of a fire is so rapid in a pneumatic conveying system that immediate and reliable actuation of the automatic extinguishing system is critical. In addition, detection and extinguishing system components are often located in harsh environments. This demands specific circuit styles that provide reliable operation in spite of fault conditions including single opens and grounds.

A-3-9.3.6 NFPA 72, *National Fire Alarm Code,* provides precise performance criteria for the different types of circuits that might be employed for fire protective signaling systems. Due to the adverse environments associated with most of the detectors, it is appropriate to require system and circuit operation in spite of the presence of opens and grounds on the detection circuits. The performance demands for the fire detection devices in these types of systems necessitates this circuit classification. *(Refer to NFPA 72.)*

A-3-9.3.7 NFPA 72, *National Fire Alarm Code,* provides precise performance criteria for the different types of circuits that might be employed for fire protective signaling systems. In most facilities, there is more than one notification appliance, providing a degree of redundancy. In addition, the operation of the automatic extinguishing system proceeds regardless of the status of the notification appliance circuits. The somewhat less stringent performance demands for the fire detection notification appliances in these types of systems allows for this circuit classification. (*Refer to NFPA 72.*)

A-3-9.3.8 NFPA 72, *National Fire Alarm Code,* provides precise performance criteria for the different types of circuits that might be employed for fire protective signaling systems. The development of a fire is so rapid in a pneumatic conveying system, immediate and reliable actuation of the automatic extinguishing system is critical. In addition, these releasing devices are often located in harsh environments. This demands a circuit style that can provide operation in spite of fault conditions including single opens and grounds. The performance demands for the fire extinguishing system releasing devices in these types of systems necessitates the circuit classification. *(Refer to NFPA 72.)*

A-3-9.3.9 NFPA 72, *National Fire Alarm Code,* provides precise performance criteria for the different types of circuits that might be employed for fire protective signaling systems. Due to the adverse environments associated with most of the supervisory devices, it is appropriate to require system and circuit operation in spite of the presence of opens and grounds on the detection circuits. The performance demands for the fire detection system supervisory devices such as water flow switches, pressure switches, and heat-trace operating and monitoring devices in these types of systems necessitates this circuit classification. *(Refer to NFPA 72.)*

A-3-9.3.10 NFPA 72, *National Fire Alarm Code,* provides precise performance criteria for the different types of circuits that might be employed for fire protective signaling systems. The development of a fire is so rapid in a pneumatic product conveying system that immediate and reliable actuation of the abort gates and dampers is critical. In addition, these releasing devices are often located in harsh environments. This demands a circuit style that can provide operation in spite of fault conditions including single opens and grounds. The performance demands for the fire extinguishing system releasing devices in these types of systems necessitates this circuit classification. *(Refer to NFPA 72.)*

A-3-9.3.14 A spark/ember detection and extinguishing system primer has been included as Appendix B of this standard. *(See Appendix B, Informational Primers on Prevention and Extinguishing Systems.)*

A-4-1.1 See Figure A-4-1.1(a) and Figure A-4-1.1(b) for examples of foreign material removal.

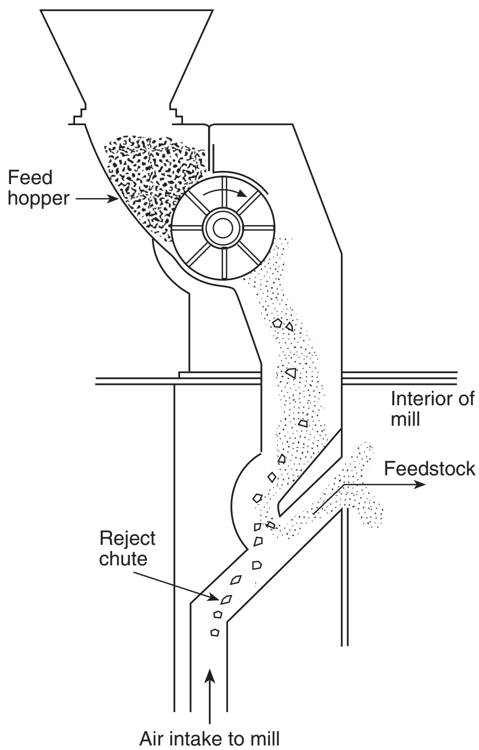


Figure A-4-1.1(a) Pneumatic separator.

A-4-1.2 Use of direct drive for transmission of power is preferable where possible, to the use of belt or chain drivers.

A-4-1.3 Consideration should be given to the potential for overheating caused by dust entry into bearings. Bearings should be located outside the combustible dust stream where they are less exposed to dust and more accessible for inspection and service. Where bearings are in contact with the particulate solids stream, sealed or purged bearings are preferred.

A-4-2 For additional information on electrical equipment, refer to NFPA 70, *National Electrical Code,* Articles 500, 501, 502, and 503 and NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

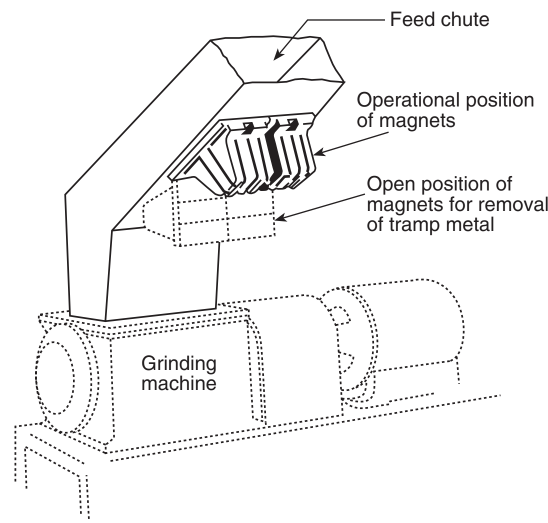


Figure A-4-1.1(b) Magnetic separator.

A-4-3 See NFPA 77, *Recommended Practice on Static Electricity,* for information on this subject.

A-4-3.1 Bonding minimizes the potential difference between conductive objects. Grounding minimizes the potential difference between objects and ground.

A-4-3.3 The inability to generate an incendive spark by certain FIBCs is documented.[3]

A-4-4 Powder-actuated tools use a propellant similar to gunpowder to drive the fastener. The use of these tools produces a flame that can be an ignition source and should be used only under a hotwork permit system.

A-5-1.2(e) Process interlocks should be calibrated and tested in the manner in which they are intended to operate with written test records maintained for review by management. Testing frequency should be determined in accordance with the Center for Chemical Process Safety document, *Guidelines for Safe Automation of Chemical Processes.*

A-5-2.2.4 This is especially important if the blower or fan is exposed to heated air.

A-5-2.2.5 If rust is allowed to form on the interior steel surfaces it is only a matter of time before an iron oxide (rust) becomes dislodged and is taken downstream, striking against the duct walls. In some cases this might cause an ignition of combustibles within the duct. The situation becomes worse if aluminum paint is used. When the aluminum flakes off or is struck by a foreign object, the heat of impact might be sufficient to cause the ignition of the aluminum particle, thereby initiating a fire downstream.

A-5-2.5.3 For information on maintenance of deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations.*

A-6-2.1.1 Whether a metallic particulate reacts with water depends on particle size, chemical purity of the particulate, oxygen concentration, and combustion temperature. Consequently, an engineering analysis should be performed prior to selecting an extinguishment strategy. There are some cases where a rapidly discharged high-volume water spray system has been shown to be effective due to the rapid absorption of heat.

Metals commonly encountered in a combustible form include cadmium, chromium, cobalt, copper, hafnium, iron, lead, manganese, molybdenum, nickel, niobium, palladium, silver, tantalum, vanadium, and zinc. While these are generally considered less combustible than the alkali metals (aluminum, magnesium, titanium, and zirconium), they still should be handled with care when in finely divided form.

In many cases, water will be an acceptable extinguishing agent if used properly. Many infrared spark/ember detectors are capable of detecting burning particles of these metals. Consequently, these metal particulates can often be treated as combustible particulate solids without the extremely hazardous nature of the alkali metals.

Using a bulk density of 75 lb/ft^3 (1200 kg/m^3) and an assumed concentration of 0.35 oz/ft^3 (350 g/m^3), it has been calculated that a dust layer that averages $^1/_{32}$ in. (0.8 mm) thick covering the floor of a building is sufficient to produce a uniform dust cloud of optimum concentration, 10 ft (3 m) high, throughout the building. This is an idealized situation and several factors should be considered.

First, the layer will rarely be uniform or cover all surfaces and, second, the layer of dust will probably not be completely dispersed by the turbulence of the pressure wave from the initial explosion. However, if only 50 percent of the $^1/_{32}$-in. (0.8-mm) thick layer is suspended, this is still sufficient material to create an atmosphere within the explosible range of most dusts.

Consideration should be given to the proportion of the building volume that could be filled with a combustible dust concentration. The percentage of floor area covered can be used as a measure of the hazard. For example, a 10 ft × 10 ft (3 m × 3 m) room with a $^1/_{32}$-in. (0.8-mm) layer of dust on the floor is obviously hazardous and should be cleaned. Now consider this same 100 ft^2 (9.3 m^2) area in a 2025-ft^2 (188-m^2) building; this also is a moderate hazard. This area represents about 5 percent of a floor area and is about as much coverage as should be allowed in any plant. To gain proper perspective, the overhead beams and ledges should also be considered. Rough calculations show that the available surface area of the bar joist is about 5 percent of the floor area. For steel beams, the equivalent surface area can be as high as 10 percent.

From the information in the preceding paragraph, the following guidelines have been established:

(a) Dust layers $^1/_{32}$ in. (0.8 mm) thick can be sufficient to warrant immediate cleaning of the area [$^1/_{32}$ in. (0.8 mm) is about the diameter of a paper clip wire or the thickness of the lead in a mechanical pencil].

(b) The dust layer is capable of creating a hazardous condition if it exceeds 5 percent of the building floor area.

(c) Dust accumulation on overhead beams and joists contributes significantly to the secondary dust cloud and is approximately equivalent to 5 percent of the floor area. Other surfaces, such as the tops of ducts and large equipment, can also contribute significantly to the dust cloud potential.

(d) The 5 percent factor should not be used if the floor area exceeds 20,000 ft^2 (1858 m^2). In such cases, a 1000 ft^2 (93 m^2) layer of dust is the upper limit.

(e) Due consideration should be given to dust that adheres to walls, since this is easily dislodged.

(f) Attention and consideration should be given to other projections such as light fixtures that can provide surfaces for dust accumulation.

(g) Dust collection equipment should be monitored to be certain it is operating effectively. For example, dust collectors using bags operate most effectively between limited pressure drops of 3 in. to 5 in. (0.74 kPa to 1.24 kPa) of water. An excessive decrease or low drop in pressure indicates insufficient coating to trap dust.

The guidelines listed in (a) through (g) will serve to establish a cleaning frequency.

A-8-2 A relatively small initial dust explosion will disturb and suspend in air dust that has been allowed to accumulate on the flat surfaces of a building or equipment. This dust cloud provides fuel for the secondary explosion, which usually causes the major portion of the damage. Reducing dust accumulations is, therefore, a major factor in reducing the hazard in areas where a dust hazard can exist.

A-8-3 Vacuum cleaning systems are preferred for this purpose.

Appendix B Informational Primers on Prevention and Extinguishing Systems

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 Spark Detection and Extinguishing Systems Prime Design Concepts.

B-1.1 Spark/ember detectors are radiant energy-sensing fire detectors. The design, installation, and maintenance of radiant energy-sensing fire detectors is covered in Chapter 5 of NFPA 72, *National Fire Alarm Code.* Where required by this standard, spark detectors are used to actuate an abort gate to divert fuel, flames, and combustion gases to a safe location. However, they are more commonly integrated into a spark detection and extinguishing system. In this second case, the extinguishment is usually an intermittent water spray designed and installed pursuant to NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* and maintained pursuant to NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.* Since the overwhelming majority of the applications that employ spark/ember detectors are pneumatic conveying systems, it is appropriate to provide a primer on these devices as part of this standard.

B-1.2 When spark detectors are used to actuate an abort gate, the design concepts are fairly straightforward. The detectors are mounted on the duct upstream from the abort gate. The detectors are wired to a control panel listed and approved for the purpose. When the detector senses a spark, the signal causes the control panel to alarm and the solenoid or other releasing device on the abort gate is energized. This type of system is shown in Figure B-1.2.

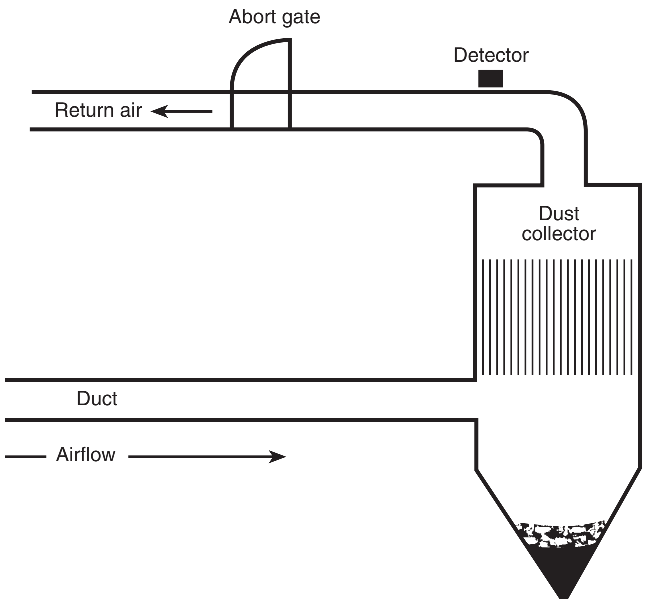


Figure B-1.2 Spark detectors and abort gate.

B-1.3 Spark detection and extinguishment systems usually consist of a group of detectors located on the conveying duct, a control panel in a safe accessible location, and extinguishment solenoid valve and nozzle set located on the duct downstream from the detectors. This is shown in Figure B-1.3.

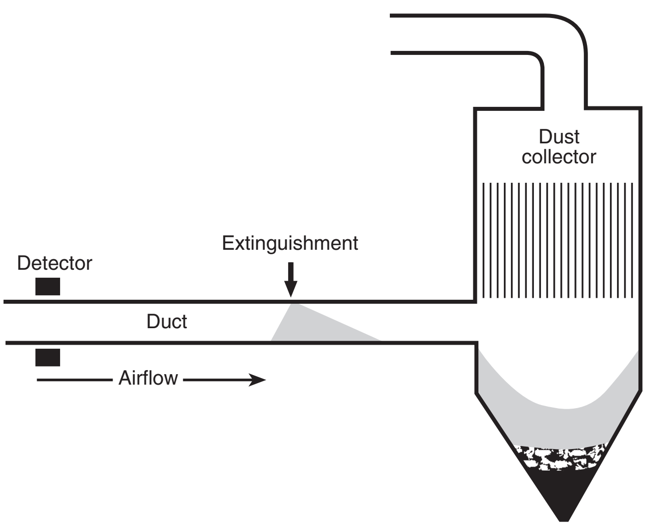


Figure B-1.3 The typical spark detection and extinguishment system.

B-1.4 When a spark (ember) enters the detector(s), the system responds with an alarm signal that actuates the extinguishing system valve, establishing an extinguishing concentration of water, before the spark arrives. The water spray is maintained for a time period long enough to ensure extinguishment and is then turned off. This minimizes the quantity of water injected into the duct. The pneumatic conveying system is not shut down. It continues to run. Each time a spark comes down the duct it is quenched.

B-1.5 For both system design concepts, several critical factors should be addressed if they are to work. First, the detector should be able to reliably detect a spark, ember, or flame. Second, the alarm signal should be processed quickly. The timing should be predictable enough to allow the abort gate to operate or allow the extinguishing system sufficient time to establish the water spray. Finally, in the case of the extinguishing system, there should be a provision to re-apply the water-spray extinguishment repetitively. The occurrence of a spark is rarely an isolated incident; usually sparks are produced in a burst or stream. The extinguishing system should be able to reactivate as each successive spark is detected. Unless all of these concerns are addressed, spark/ember detection and extinguishment cannot be used as usually supplied.

B-1.6 The first concern is the ability to detect a spark, ember, or fire. NFPA 72, *National Fire Alarm Code,* defines a spark as "a moving ember" and defines an ember as "a particle of solid material that emits radiant energy due to either its temperature or the process of combustion on its surface." Figure B-1.6 shows the radiation intensity as a function of wavelength for an oak ember and a gasoline flame.

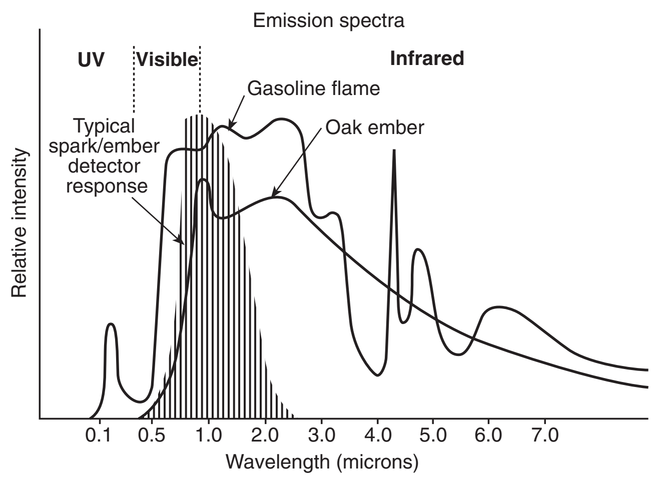


Figure B-1.6 The emissions of an oak ember and gasoline flame compared to the spectral sensitivity of a spark/ember detector.

B-1.7 The spectral sensitivity of the typical spark/ember detector is superimposed upon the graph. One can see that the spark/ember detector will sense the radiation from both an ember (spark) and a flame.

B-1.8 The next question regarding the deductibility of a spark or flame in the duct is the sensitivity and speed of the detector. Since the detector is designed to be mounted on a duct that is dark, silicon photodiode sensors can be used and there will be few, if any, sources of spurious alarm within the duct. This allows the detectors to be made both extremely sensitive and extremely fast. Sensitivities of 1.0 microwatts and speeds of 100 microseconds are common. The result is a detector that can detect a spark the size of a pinhead moving faster than the speed of sound. The outcome is that both sparks and flames are easily detected in pneumatic conveying systems with modern spark/ember detectors. (Caution: The sensitivity of spark/ember detectors is quite speed sensitive. If the fire is moving too slowly, the typical spark/ember detector might not detect it. In general, spark/ember detectors will not detect a stationary ember or flame.)

B-1.9 The second consideration is the absolute necessity for a predictable time between the detection of the spark and the actuation of the abort gate or the establishment of the water spray extinguishing concentration. The response times of the detector, control panel, and solenoid valve are known, verified, and extremely reliable. However, unless the arrival time of the spark at the abort gate or extinguishing water spray is equally predictable, these systems are not appropriate.

B-1.10 The arrival time of the spark is a function of the conveying system air speed and the distance between the detector and the extinguishing system. Actually, most spark detection and extinguishment systems provide designers with a formula they can use to compute the required distance between the detectors and the abort gate or extinguishment. Generally, it is in the following form:

$$(\text{Air Speed}) \times (\text{System Factor}) = \begin{array}{l}\text{Distance Between}\\ \text{Detectors and}\\ \text{Exstinguishment}\end{array}$$

B-1.11 The air speed and hence the ember speed should be both constant and controlled. It is this necessity that established the requirement that the combustible concentration be less than one-half the LFL or MEC. If the combustible concentration exceeds the LFL or MEC, a deflagration can result from the introduction of a spark. The speed of the flame front equals the sum of the flame front velocity for that combustible at that concentration plus the nominal air velocity of the conveying system. The deflagration flame front would pass the abort gate before it opened or pass the extinguishment before the valve had opened and established a spray pattern. This is why the criteria regarding combustible concentration are so important. A spark detection system on a conveying line where the concentrations are above the LFL or MEC cannot be expected to make a meaningful contribution to the survival of the site or its occupants should a deflagration occur.

B-1.12 Finally, since the cause of the first spark usually causes additional sparks, the control panel should be designed for the successive and repetitive reapplication of the extinguishing agent. This type of function is not found in the average fire alarm control panel. Specially designed control panels, specifically designed for spark detection and extinguishment are the norm.

B-2 System Basics.

B-2.1 This standard requires the use of spark detection systems in those installations where conveying air is being returned to the building. It requires that the spark detection be used to activate an abort gate, diverting the air stream to outside ambient. This is a critical life safety and property-conservation measure. Sparks entering a dust collector are apt to initiate a deflagration. If the abort gate was not activated, the flames and combustion gases would be conveyed back into the facility, igniting secondary fires and posing a serious threat to the occupants. Figure B-2.1 is a diagram of this type of system.

B-2.2 Since spark detectors have limited fields of view, most systems require two detectors to cover a round duct. The detectors are usually situated on the inlet to the collector as shown. This is the only type of spark detection system that is required by the standard. However, as a minimum compliance standard it does allow additional measures.

B-2.3 The problem with this minimum compliance approach is that it can often reduce the productivity of the site. When a spark is detected, the abort gate transfers. Now the air-handling system should be shut down in order to restore the abort gate to the normal position. This might require an hour of production time. If a spark is a rare occurrence then this is not a serious problem. However, in many systems sparks are a common occurrence. For example, in a woodworking facility one might expect several sparks per day. Obviously, a system that shuts down the facility for an hour several times a day is not a viable system.

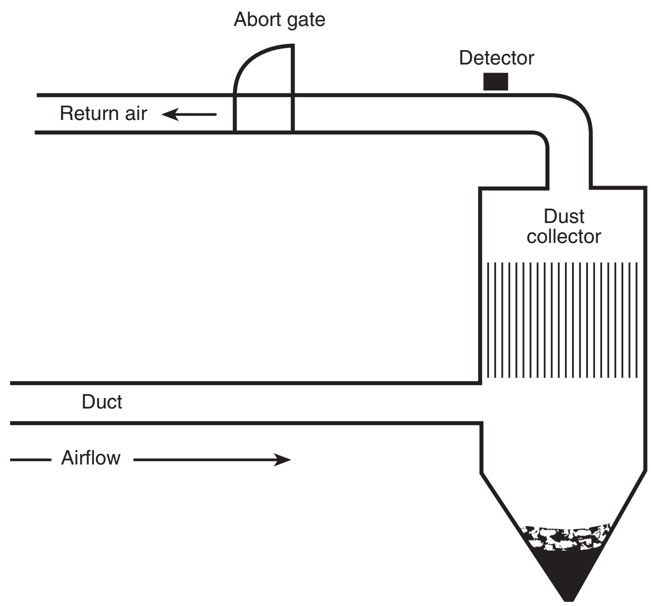


Figure B-2.1 The minimum compliance spark detection system.

B-2.4 The use of a spark detection and extinguishment system on the inlet to the dust collector is an extremely effective way of preventing the production stoppages. A second "zone" of spark detectors is mounted on the pneumatic conveying duct far enough upstream to allow the installation of an intermittent water spray extinguishing system on the inlet duct prior to entry into the primary dust collector (air-material separator). This spark detection and extinguishment system quenches each spark as it comes down the duct, before it reaches the air-material separator. Properly designed and installed spark detection and extinguishment systems are very effective in preventing ignitions in the AMSs. The spark detector that activates the abort gate is moved to the outlet of the AMS, providing a secondary detection. This type of system is shown in Figure B-2.4.

B-2.5 The spark detection and extinguishment system involves more than just detectors and a water spray. In order for the system to provide the degree of performance necessitated by the application, there are a number of additional system attributes that should be deemed mandatory.

First, the detectors should be listed and approved to operate in conjunction with the control panel and the water spray extinguishing unit. All three components should be listed as a system. The nozzles used are specifically designed for this type of service; they are not "off the shelf" sprinkler heads. The solenoid valve is specifically matched to the control panel to ensure a uniform, predictable response time.

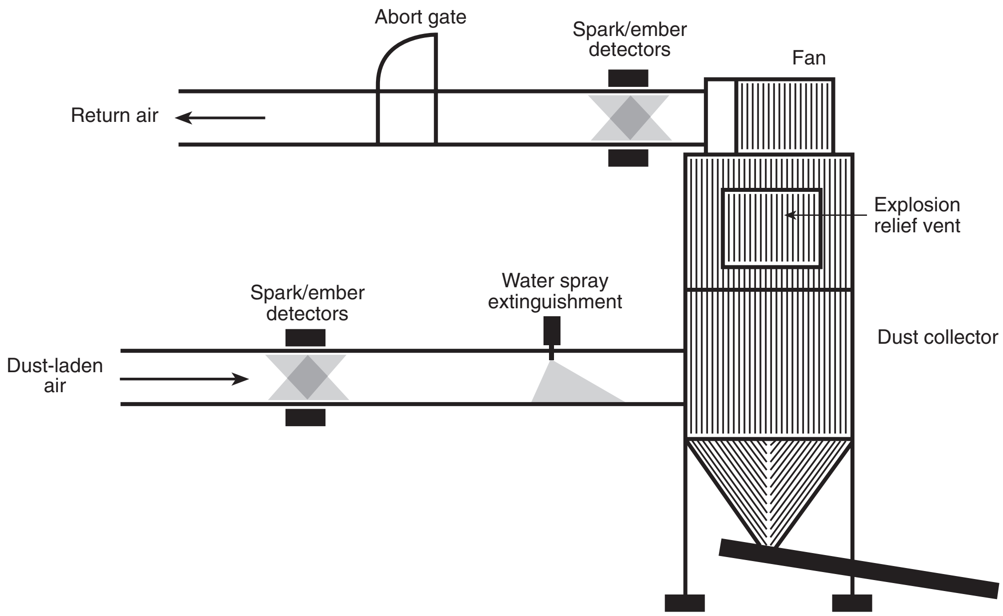


Figure B-2.4 The basic spark detection and extinguishment system for a single air-material separator.

The operating requirements of a spark-detection and extinguishing system require additional features. The windows or lenses of detectors can become scratched, broken, or coated with material, reducing the sensitivity. Consequently, a means should be provided to measure the sensitivity of the detectors to make certain that they are capable of detecting sparks after the initial installation tests. The sensitivity measurement capability is required by NFPA 72, *National Fire Alarm Code*. If the material is discovered to cling to the interior surfaces of the duct, a means to keep the detector window/lens clean is required by NFPA 72. This usually involves an air-purging option that baths the detector window/lens with clean air.

In order for the extinguishing system to work reliably it should have a strainer (required by NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*) to prevent pipe scale from clogging the nozzle. The water supply should be reliable and supervised with a pressure switch. Since the extinguishment system components are mounted on a duct that might be outside, freeze-prevention measures should be implemented. Antifreeze solutions are not a viable option on extinguishing systems that are expected to operate regularly. Consequently, heat-tracing should be thought of as a mandatory constituent of the system along with the thermostats to turn the heat-trace on and to warn of impending freeze-up.

Finally, there are desirable system components such as system testing, event recording, and flow indicators that should be considered as part of any system.

Appendix C Referenced Publications

C-1 The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not considered part of the requirements of this standard unless also listed in Chapter 9. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this standard.

C-1.1 Appendix A References.

1. R. Siwek, "New Knowledge About Rotary Air Locks in Preventing Dust Ignition Breakthrough," *Plant Operations Progress,* Vol. 8, No. 3, July 1989, pp. 165-176.

2. R. Siwek, "A Review of Explosion Isolating Techniques," Europex International Seminar, March 1996.

3. V. Ebadat, "Testing the Suitability of FIBCs for Use in Flammable Atmospheres," AIChE 30th Annual Loss Prevention Symposium, New Orleans, LA, February 1996.

C-1.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 1996 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 1998 edition.

NFPA 68, *Guide for Venting of Deflagrations,* 1994 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 1997 edition.

NFPA 70, *National Electrical Code®,* 1996 edition.

NFPA 72, *National Fire Alarm Code®,* 1996 edition.

NFPA 77, *Recommended Practice on Static Electricity,* 1993 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials,* 1995 edition.

NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas,* 1997 edition.

C-1.3 Other Publications.

C-1.3.1 ASTM Publication. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM C 582, *Standard Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment,* 1995.

C-1.3.2 SMACNA Publications. Sheet Metal and Air Conditioning Contractors' National Association, Inc., P.O. Box 221230, Chantilly, VA 22022-1230.

Accepted Industry Practice for Industrial Duct Construction, 1975.

Rectangular Industrial Duct Construction Standards, 1980.

Round Industrial Duct Construction Standards, 1977.

Thermoplastic Duct (PVC) Construction Manual, 1974.

C-1.3.3 Other Publication. Center for Chemical Process Safety, American Institute of Chemical Engineers, 345 East 47th Street, New York, NY, 10017.

Guidelines for Safe Automation of Chemical Processes, 1993.

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