NFPA 654

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

1997 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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This edition of NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of 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 Annual Meeting held May 19–22, 1997, in Los Angeles, CA. It was issued by the Standards Council on July 24, 1997, with an effective date of August 15, 1997, and supersedes all previous editions.

This edition of NFPA 654 was approved as an American National Standard on August 15, 1997.

Origin and Development of NFPA 654

NFPA 654 was initiated by the Committee on Dust Explosion Hazards in 1943 and originally applied only to the prevention of dust explosions in the plastics industry. As such, it was tentatively adopted in 1944 and officially adopted in 1945. Amendments were adopted in 1946, 1959, 1963, and 1970. The 1970 edition was reconfirmed in 1975.

In 1976, responsibility for NFPA 654 was transferred to the Technical Committee on Fundamentals of Dust Explosion Prevention and Control. The Committee, in completely revising the document, also expanded its scope to include chemical, dye, and pharmaceutical dusts, since the fire and explosion hazards of these dusts are generally the same as for plastic dusts.

The 1982 edition of this standard consisted of a complete rewrite of the 1975 edition. Due to limited technological changes in this area since 1982, the Committee voted to reconfirm the text as it appears in the 1982 version. Editorial corrections and changes that allow the document to adhere more closely to the NFPA *Manual of Style* were incorporated into the 1988 edition.

For the 1994 edition of NFPA 654, the standard was revised to improve its usability, adoptability, and enforceability; to update outdated terminology; and to add the NFPA language for equivalency and retroactivity. In addition, the Technical Committee on Fundamentals of Dust Explosion Prevention and Control added new technologies for explosion prevention to be consistent with the 1992 edition of NFPA 69, *Standard on Explosion Prevention Systems.* The Committee also clarified the requirements relating to controlling hazardous accumulations of process dust.

For the 1997 edition, the Committee completely revised the standard to incorporate new processing and explosion protection technologies. The title of the document was revised to reflect that the standard encompasses all industries not otherwise included in previous editions of the standard, including the fibers industry. The complete revision incorporated 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.

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in membership may have occurred. A key to classifications is found at the back of this document.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

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Standard for the

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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 General

1-1 Scope.

1-1.1* This standard shall apply to all phases of the manufacture, processing, blending, repackaging, and handling of combustible particulate solids, combustible dusts, or hybrid mixtures, regardless of concentration or particle size, where the materials present a fire or explosion hazard.

1-1.2 This standard shall not apply to materials covered by the following:

(a) NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*

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

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

(d) NFPA 120, *Standard for Coal Preparation Plants*

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

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

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

(h) NFPA 485, *Standard for the Storage, Handling, Processing, and Use of Lithium Metal*

(i) NFPA 495, *Explosive Materials Code*

(j) NFPA 651, *Standard for the Manufacture of Aluminum Powder*

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

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

(m) NFPA 1124, *Code for the Manufacture, Transportation, and Storage of Fireworks*

(n) NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*

(o) NFPA 8503, *Standard for Pulverized Fuel Systems*

1-1.3 NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials,* shall not apply to material transfer systems or dust control systems covered by this standard.

1-2 Purpose. The purpose of this standard is to prescribe requirements for safety to life and property from fire and explosion and to minimize the resulting damage should a fire or explosion occur.

1-3 Equivalency. Nothing in this standard is 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 submitted 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 are 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 is not 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 adjacent property.

1-4.1 This standard applies to facilities on which construction is begun subsequent to the date of publication of the standard. When major replacement or renovation of existing facilities is planned, provisions of this standard shall apply.

1-4.2 As used in this standard, the term "dust" shall be interchangeable with "combustible dust," "combustible fiber," or "combustible flake" and shall identify finely divided particulate solids that present a fire or deflagration hazard.

1-5 Definitions. For the purpose of this standard, the following terms shall have the meanings given below.

Air-Moving Device (AMD). A power-driven fan, blower, or other device that establishes an airflow by moving a volume of air per unit time.

Approved.* Acceptable to the authority having jurisdiction.

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

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 or deflagration hazard.

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

Compartmentation. The interposing of a physical barrier, which is not required to be fire or explosion resistant, to limit combustible particulate solid migration in order to control the size of a hazard area.

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

Detachment. The locating of a combustible particulate solid process in the open air or in a separate building.

Dryer. A piece of processing equipment using temperature or pressure change to reduce the moisture or volatile content of the material being handled.

Duct. Pipes, channels, or other enclosures used for the purpose of conveying air, dust, or gas.

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

Hybrid Mixture.* A mixture of a combustible dust with either a flammable gas or a combustible mist.

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.

Replacement-in-Kind. A replacement that satisfies the design specification.

Segregation. The interposing of a fire and explosion-resistant barrier between the combustible particulate solid process and other operations.

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.

Chapter 2 Facility and Systems Design

2-1 General. The provisions of this section address the overall design of systems handling combustible particulate solids.

2-1.1 Systems handling combustible particulate solids shall be designed by and installed under the supervision of persons having knowledge of these systems and their associated hazards.

2-1.2 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

2-1.3* The design basis and design shall be documented and shall include the properties defining the hazards of the material being processed.

2-2 Segregation, Separation, or Detachment of Combustible Dust Handling and Processing Areas.

2-2.1 General. Areas in which combustible dusts are processed or handled shall be detached, segregated, or separated from other occupancies to minimize damage if a fire or explosion occurs.

2-2.2 Use of Segregation.

2-2.2.1 Physical barriers erected to segregate dust hazards shall have all penetrations of floors, walls, ceilings, or partitions sealed dust-tight and, where structural assemblies have a fire endurance rating, the seal shall maintain that rating.

2-2.2.2 Physical barriers erected to segregate dust deflagration hazards shall be designed for sufficient explosion resistance to preclude failure of these barriers before the deflagration pressure can be safely vented to the outside. *(For deflagration venting, see Section 2-4.)*

2-2.3 Use of Separation.

2-2.3.1 When separation is used to limit the fire or dust explosion hazard area, the hazard area shall include areas where dust accumulations exceed $^1/_{32}$ in. (0.8 mm) or where dust clouds of a hazardous concentration exist.

2-2.3.2 The required separation distance between the hazardous area identified in 2-2.3.1 and surrounding exposures shall be determined by an engineering evaluation addressing the properties of the materials, the type of operation, the amount of material likely to be present outside the process equipment, the design of the building, and the nature of surrounding exposures. In no case shall the distance be less than 30 ft (9 m).

2-2.3.3 When separation is used, housekeeping, fixed dust collection systems employed at points of release, and compartmentation shall be permitted to be used to limit the extent of the hazardous area.

2-3 Building Construction.

2-3.1 All buildings shall be of Type I or II construction, as defined in NFPA 220, *Standard on Types of Building Construction.* Where local, state, and national building codes require, modifications shall be permitted for conformance to these codes.

2-3.2* Interior surfaces where dust accumulations can occur shall be designed and constructed to facilitate cleaning and minimize combustible dust accumulations.

Exception: Sealing of penetrations shall not be required when the penetrated barrier is provided for reasons other than to limit the migration of dusts or to control the spread of fire or explosion.

2-3.3 Spaces inaccessible to housekeeping shall be sealed to prevent dust accumulation.

2-3.4 Interior walls erected for the purpose of limiting fire spread shall have a minimum 1-hr fire resistance rating and shall be designed in accordance with NFPA 221, *Standard for Fire Walls and Fire Barrier Walls.*

2-3.5 Openings in fire walls and fire barrier walls shall be protected by self-closing fire doors having a fire resistance rating equivalent to the wall design. Fire doors shall be installed according to NFPA 80, *Standard for Fire Doors and Fire Windows,* and shall normally be in the closed position.

2-3.6 Means of egress shall comply with NFPA *101®, Life Safety Code.*

2-3.7 All penetrations of floors, walls, ceilings, or partitions shall be dust-tight and, where structural assemblies have a fire endurance rating, the seal shall maintain that rating.

2-3.8 Interior stairs, elevators, and manlifts shall be enclosed in dust-tight shafts having a minimum fire resistance rating of 1 hr. Doors of the automatic-closing or self-closing type, having a fire resistance rating of 1 hr, shall be provided at each landing.

Exception: Stairs, elevators, and manlifts serving only open-deck floors, mezzanines, and platforms need not be enclosed.

2-3.9* Floors and load-bearing walls exposed to dust explosion hazards shall be designed to preclude failure during an explosion.

2-4* Deflagration Venting.

2-4.1* If a room or building contains a dust explosion hazard external to protected equipment as defined in 2-2.3.1, such areas shall be provided with deflagration venting to a safe outside location.

2-4.2* Vent closures shall be directed toward a personnel restricted area, or the vent closure shall be restrained to minimize the missile hazard to personnel and equipment. The fireball emitted from the vent opening shall not impinge upon personnel pathways.

2-5* Relief Valves. Relief valves shall not be vented to a dust hazard area as defined by 2-2.3.1.

2-6 Equipment Arrangement. Equipment shall be located or arranged in a manner that minimizes combustible dust accumulations on hot surfaces.

2-7 Electrical Equipment.

2-7.1 All electrical equipment and installations shall comply with the requirements of NFPA 70, *National Electrical Code®*, or NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment.*

2-7.2* In local areas of a plant where a hazardous quantity of dust accumulates or is present in suspension in the air, the area shall be classified and all electrical equipment and installations in those local areas shall comply with Article 502 or Article 503 of NFPA 70, *National Electrical Code,* as applicable.

2-7.3 All hazardous (classified) areas identified in accordance with 2-7.2 shall be documented, and such documentation shall be permanently maintained on file for the life of the facility.

2-8 Management of Change. Written procedures shall be established and implemented to manage change to process materials, technology, equipment, procedures, and facilities. The requirements of 2-8.1 through 2-8.2 shall be applied retroactively.

2-8.1 The procedures shall ensure that the following are addressed prior to any change:

(a) The technical basis for the proposed change

(b) Safety and health implications

(c) Whether the change is permanent or temporary

(d) Modifications to operating and maintenance procedures

(e) Employee training requirements

(f) Authorization requirements for the proposed change

Exception: Implementation of the management of change procedure shall not be required for replacements-in-kind.

2-8.2 Design documentation, as required by 2-1.3, shall be updated to incorporate the change.

Chapter 3 Process Equipment

3-1 General. This chapter prescribes methods of explosion protection for specific equipment.

Exception: A documented risk evaluation acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of explosion protection to be provided.*

3-1.1 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

(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.)

3-1.2* Equipment Isolation.

3-1.2.1 Isolation devices shall be provided to prevent deflagration propagation between pieces of equipment connected by ductwork. Isolation devices include, but are not limited to:

(a) * Chokes

(b) * Rotary valves

(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) * Flame front extinguishing systems in accordance with NFPA 69, *Standard on Explosion Prevention Systems*

Exception No. 1: Isolation devices are not required when oxidant concentration has been reduced or when the dust has been rendered noncombustible in accordance with 3-1.1(a) or (e).*

Exception No. 2: Isolation devices are not required if a documented risk evaluation acceptable to the authority having jurisdiction determines that deflagration propagation will not occur.*

3-1.2.2* Isolation devices shall be provided to prevent deflagration propagation from air material separators to work areas. Isolation devices include, but are not limited to, those listed in 3-1.2.1(a)* through (e)*.

Exception: Isolation devices are not required if a documented risk evaluation acceptable to the authority having jurisdiction determines that deflagration propagation will not occur.

3-2 Bulk Storage.

3-2.1 For the purpose of this section, bulk storage shall include such items as bins, tanks, hoppers, and silos.

3-2.2 Bulk storage containers, whether located inside or outside of buildings, shall be constructed of noncombustible material.

3-2.3 There shall be no intertank or interbin venting.

3-2.4* Interior surfaces shall be designed and constructed to facilitate cleaning and minimize combustible dust accumulation.

3-2.5* Access Doors and Openings.

3-2.5.1 Access doors or openings shall be provided to permit inspection, cleaning, and maintenance.

3-2.5.2 Access doors or openings shall be designed to prevent dust leaks.

3-2.5.3 Access doors or openings that are not specifically designed for deflagration venting shall not be considered as providing that function.

3-2.6 Fixed bulk storage containers shall be provided with explosion protection as described in 3-1.1.

Exception No. 1: Explosion protection requirements per 3-1.1 shall be permitted to be omitted if the volume of the fixed bulk storage container is less than 8 ft^3 (0.227 m^3).*

Exception No. 2: The requirements of this section do not apply to containers that are used for transportation of the material.*

3-3 Material Transfer System.

3-3.1 Duct Systems.

3-3.1.1* Ducts handling combustible particulate solid shall have the following features:

(a) * Construction that is conductive, bonded, and grounded in accordance with Section 5-3*, Static Electricity

(b) Rigid, noncombustible material construction

(c) Adequate strength to meet the conditions of service and installation requirements

(d) Proper protection where subject to damage

(e) Thorough bracing and support by metal hangers and brackets

(f) Design that affords strength and rigidity against disruption.

(g) Arrangement such that all lap joints are made in the direction of the airflow

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

3-3.1.2 All ducts shall be made dust-tight 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 vents.

3-3.1.3* Changes in sizes of ducts shall be designed to prevent the accumulation of material.

3-3.1.4 Ducts shall not pass through a fire wall, as defined by NFPA 221, *Standard for Fire Walls and Fire Barrier Walls.*

3-3.1.5 If ducts pass through a fire barrier wall having a fire resistance rating of 2 hr 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-hr fire scenario, or 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

3-3.1.6 If ducts pass through a fire barrier wall having a fire resistance rating of less than 2 hr, 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

3-3.1.7* When 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.

3-3.2* Bucket Elevators.

3-3.2.1* Bucket elevators shall be provided with deflagration venting. When bucket elevators are located within the building, deflagration vents shall be ducted to the outside.

Exception: As an alternative to deflagration venting, bucket elevators shall be permitted to be protected in accordance with 3-1.1(a), (c), (d), (e), or 3-1.2.1(e)*.*

3-3.2.2 Elevator casings, head and boot sections, and connecting ducts shall be dust-tight and shall be constructed of noncombustible materials.

3-3.2.3 Where provided, inlet and discharge hoppers shall be designed to be accessible for cleaning and inspection.

3-3.2.4 Belt-driven bucket elevators shall be provided with a detector that will cut off the power to the drive motor if the motor speed drops below 80 percent of normal operating speed. Feed to the elevator leg shall be stopped or diverted.

3-3.2.5 Belt-driven bucket elevators shall have a nonslip material (lagging) installed on the head pulley to minimize slippage. Belts and lagging shall have a surface resistivity not greater than 100 meg-ohm per square, and be fire resistant and oil resistant.

3-3.2.6 No bearings shall be located within the bucket elevator casing.

3-3.2.7* Head and boot sections shall be provided with openings for clean-out, inspection, and alignment of the pulley and belt.

3-3.2.8* The bucket elevator shall be driven by a motor and drive train capable of handling the full-rated capacity of the elevator without overloading. The drive shall be capable of starting the unchoked elevator under full (100 percent) load.

3-3.2.9 Elevators shall have monitors at head and tail pulleys that indicate high bearing temperature or vibration detection, head pulley alignment, and belt alignment. Abnormal conditions shall actuate an alarm requiring corrective action.

Exception: This requirement does not apply to elevators that have belt speeds below 500 ft/min (2.5 m/sec) or capacities less than 3750 ft^3/hr (106 m^3/hr).

3-3.2.10 All bins into which material is directly discharged from the bucket elevator, and that are not designed with automatic overflow systems, shall be equipped with devices to shut down equipment or with high-level indicating devices with visual or audible alarms.

3-3.3* Enclosed Conveyors.

3-3.3.1 Housings for enclosed conveyors (e.g., screw, drag) shall be of metal construction and shall be designed to prevent escape of combustible dusts. Coverings on clean-out, inspection, and other openings shall be securely fastened.

3-3.3.2* Pneumatic systems shall be designed in accordance with NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials.*

3-3.3.3 All conveyors shall be equipped with a device that shuts off the power to the drive motor and sounds an alarm in the event the conveyor plugs. Feed to the conveyor shall be stopped or diverted.

3-3.4 Air-Moving Devices (Fans and Blowers).

3-3.4.1 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/ft^3 (0.3 gm/m^3).*

Exception No. 2: Those systems operating at combustible particulate solids or hybrid mixture concentration equal to or greater than 0.0003 oz/ft^3(0.3 gm/m^3) and protected as follows:*

(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: 3-1.1(a), (d), (e), or 3-1.2(c)*, (d)*, or (e)**

(b) AMDs shall be designed, constructed, and installed using the following:

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 (if used) external to the casing*
6. *Impeller, bearings, and shaft restrained to prevent axial or lateral shift*
7. *Detection of material buildup or overheating in the AMD housing, as well as interlocking to shut off the AMD*

3-4 Size Reduction.

3-4.1 Size reduction machinery includes equipment such as mills, grinders, and pulverizers.

3-4.2 Before material is processed by size reduction equipment, foreign materials shall be removed as required by 5-1.1*.

3-4.3 Explosion protection shall be provided as specified in 3-1.1.

3-5 Particle Size Separation.

3-5.1 Particle separation devices include screens, sieves, aspirators, pneumatic separators, sifters, and similar devices.

3-5.2 Particle separation devices shall be in dust-tight enclosures.

3-5.3 Connection ducts shall be in conformance with 3-3.1.1*.

3-5.4 Explosion protection shall be provided as specified in 3-1.1.

Exception: Screens and sieves shall not be required to have explosion protection.

3-6 Mixers and Blenders.

3-6.1 Mixers and blenders shall be dust-tight.

3-6.2 Foreign materials shall be removed as required by 5-1.1*.

3-6.3 Explosion protection shall be provided as specified in 3-1.1.

3-6.4 Mixers and blenders shall be made of metal or other noncombustible material.

3-7 Dryers.

3-7.1 Dryers include tray, drum, rotary, fluidized bed, pneumatic, spray, ring, and vacuum types.

3-7.2* Heating systems shall be in accordance with Section 5-6.

3-7.3 Drying media that contact material being processed shall not be recycled to rooms or buildings.

3-7.4 Drying media shall be permitted to be recycled to the drying process if passed through a filter, dust separator, or equivalent means of dust removal.

3-7.5 Dryers shall be constructed of noncombustible materials.

3-7.6 Interior surfaces of dryers shall be designed so that accumulations of material are minimized and cleaning is facilitated.

3-7.7 Outward-opening access doors or openings shall be provided in all parts of the dryer and connecting conveyors to permit inspection, cleaning, maintenance, and the effective use of portable extinguishers or hose streams.

3-7.8 Explosion protection shall be provided as specified in 3-1.1.

3-7.9 Operating controls shall be designed, constructed, installed, and monitored so that required conditions of safety for operation of the air heater, the dryer, and the ventilation equipment are maintained.

3-7.10* Heated dryers shall have operating controls arranged to maintain the temperature of the drying chamber within the prescribed limits.

3-7.11 Heated dryers and their auxiliary equipment shall be equipped with separate excess temperature-limit controls arranged to supervise the following:

(a) Heated air supply to the drying chamber

(b) Airstream at the discharge of the drying chamber

3-7.12 Excess temperature limit controls required in 3-7.11 shall initiate an automatic shutdown. The automatic shutdown shall do the following:

(a) Sound an alarm at a constantly attended location to prompt emergency response

(b) Shut off the fuel or heat source to the dryer

(c) Stop flow of product into the dryer and stop or divert flow out of the dryer

(d) Stop all airflow into the dryer

Exception No. 1: When continued airflow into the dryer is required for cooling to prevent fire.

Exception No. 2: When continued airflow is necessary to distribute fire extinguishing media.

3-7.13 An emergency stop shall be provided that will enable manual initiation of the automatic shutdown required by 3-7.12.

3-7.14 All automatic shutdowns required by 3-7.12 shall require manual reset before the dryer can be returned to operation.

Chapter 4 Dust Control

4-1 Dust Collection.

4-1.1 Continuous suction shall be provided for processes where combustible dust is liberated in normal operation so as to minimize the escape of dust. The dust shall be conveyed to dust collectors.

4-1.2 Dust collectors shall be located outside of buildings.

Exception No. 1: Those dust collectors protected in accordance with 3-1.1(a), (c), (d), or (e).*

Exception No. 2: Those dust collectors located within 20 ft (6 m) of an exterior wall and equipped with deflagration vents vented through ducts to the outside.*

4-1.3 Dust collectors shall be protected in accordance with 3-1.1.

Exception: For dust collectors located outside of buildings, a documented risk evaluation acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of explosion protection to be provided.

4-1.4 Manifolding of dust collection ducts shall not be permitted.

Exception No. 1: Dust collection ducts from a single piece of equipment or from multiple pieces of equipment interconnected on the same process stream shall be permitted to be manifolded.

Exception No. 2: Dust collection ducts from nonassociated pieces of equipment shall be permitted to be manifolded if each of the ducts is equipped with an isolation device prior to manifolding in accordance with 3-1.2.*

Exception No. 3: For centralized vacuum cleaning systems.

4-1.5 Dust collectors shall be constructed of noncombustible materials and shall be dust-tight.

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

4-1.6 Recycling of dust collector exhaust to buildings shall be permitted if the system is designed to prevent both return of dust and transmission of energy from a fire or explosion to the building.

Exception No. 1: Recycling of dust collector exhaust to the building shall not be permitted under any circumstances when combustible gases or vapors or hybrid mixtures are involved.

Exception No. 2: Recycling of dust collector exhaust to the building shall not be permitted when the recycled stream would reduce the concentration of oxygen below 19.5 volume percent in the work area.

4-1.7 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 handling of a new material.

4-2 Housekeeping. The requirements of 4-2.1 through 4-2.3 shall be applied retroactively.

4-2.1* 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.

4-2.2* Surfaces shall be cleaned in a manner that minimizes the generation of dust clouds. Vigorous sweeping or 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 [15 psig (gauge pressure of 103 kPa)] steam or compressed air shall be used.

(d) It shall be ensured that no hot surfaces capable of igniting a dust cloud or layer exist.

4-2.3 Vacuum cleaners shall be listed for use in Class II hazardous locations or shall be a fixed-pipe suction system with remotely located exhauster and dust collector installed in conformance with Section 4-1.

Exception: Where flammable vapors or gases are present, vacuum cleaners shall be listed for Class I and Class II hazardous locations.

Chapter 5 Ignition Sources

5-1 Heat from Mechanical Sparks and Friction.

5-1.1* Foreign materials (such as tramp metal) capable of igniting combustible material being processed shall be removed from the process stream by 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

5-1.2* 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.

5-1.3* 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.

5-1.4 Equipment. Equipment with moving parts shall be installed and maintained so that true alignment is maintained and clearance is provided to minimize friction.

5-2 Electrical Equipment. All electrical equipment and installations shall comply with the requirements of Section 2-7.

5-3* Static Electricity. The requirements of 5-3.2 and 5-3.3 shall be applied retroactively.

5-3.1* 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: Where the use of conductive components is not practical, nonconductive equipment shall be permitted when either (a) or (b) are followed:

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

(b) Explosion protection is provided in accordance with 3-1.1.

5-3.2 Where belt drives are used, the belts shall be electrically conductive with a resistance of less than 1.0×10^6 ohms to ground.

5-3.3 The use of portable nonconductive bulk containers such as flexible intermediate bulk containers (FIBCs) shall not be permitted where flammable atmospheres are present.

Exception: FIBCs that are listed or tested by a recognized testing organization and shown not to ignite flammable atmospheres shall be permitted to be used. Documentation of test results shall be made available to the authority having jurisdiction.*

5-3.4 Charging Particulate Solids to Vessels. Particulate solids shall not be manually dumped directly into vessels containing flammable atmospheres (gases or vapors at a flammable concentration with an oxidant).

5-4 Cartridge-Actuated Tools. The requirements of 5-4.1 through 5-4.3 shall be applied retroactively.

5-4.1 Cartridge-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.

5-4.2 The use of cartridge-actuated tools shall be in accordance with 5-5.2.

5-4.3 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 is resumed of the dust-producing or handling machinery.

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

5-5.1 Cutting and welding shall comply with the applicable requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes.*

5-5.2 Grinding, chipping, and other operations that produce either sparks or open flame ignition sources shall be controlled by a hot work permit system in accordance with NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes.*

5-5.3 Smoking shall be permitted only in designated areas.

5-6 Process and Comfort Heating Systems.

5-6.1 In areas containing combustible dust, process and comfort heating shall be provided by indirect means.

5-6.2 Fired equipment shall be located outdoors, or in a separate, dust-free room or building.

5-6.3 Air for combustion shall be taken from a clean outside source.

5-6.4 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

5-6.5 Comfort air shall not be permitted to flow from hazardous to nonhazardous areas.

5-7 Hot Surfaces.

5-7.1* The temperature of surfaces external to process equipment, such as compressors; steam, water, process piping; ducts; and process equipment, within an area containing a combustible dust, shall be maintained below the lower of either 80 percent of the ignition temperature (in °C) or 165°C (329°F).

Exception: It shall be permitted to maintain temperatures within 80 percent of the minimum ignition temperature (in °C) of the dust layer as determined by recognized test methods acceptable to the authority having jurisdiction.

5-8 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 2-7, 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 6 Fire Protection

6-1* General. Fire extinguishing agents shall be compatible with the materials handled or processed.

6-2 Fire Extinguishers.

6-2.1 Portable fire extinguishers shall be provided throughout all buildings in accordance with the requirements of NFPA 10, *Standard for Portable Fire Extinguishers.*

6-2.2 Fire extinguishers shall be operated to minimize the generation of dust clouds during discharge.

6-3 Hose, Standpipes, and Hydrants.

6-3.1 Standpipes and hose, where provided, shall comply with NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

6-3.2 Portable spray hose nozzles listed or approved for use on Class C fires shall be provided in areas containing dust in order to limit the potential for generating unnecessary airborne dust during fire-fighting operations. Straight stream nozzles shall not be used on fires in areas where dust clouds can be generated.

6-3.3 Private outside protection, including outside hydrants and hoses, where provided, shall comply with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*

6-4* Automatic Sprinklers.

6-4.1* Where a process handling combustible particulate solids uses flammable or combustible liquids, a documented risk evaluation acceptable to the authority having jurisdiction shall be used to determine the need for automatic sprinkler protection in the enclosure in which the process is located.

6-4.2 Automatic sprinklers, where provided, shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

6-4.3 Where automatic sprinklers are installed, dust accumulation on overhead surfaces shall be minimized to prevent an excessive number of sprinkler heads from opening in the event of a fire.

6-5 Special Fire Protection Systems. Automatic extinguishing systems or special hazard extinguishing systems, where provided, shall be designed, installed, and maintained in accordance with the following standards as applicable. The extinguishing systems shall be designed and used to minimize the generation of dust clouds during their discharge.

(a) NFPA 11, *Standard for Low-Expansion Foam*

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

(c) NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*

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

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

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

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

(h) NFPA 17, *Standard for Dry Chemical Extinguishing Systems*

(i) NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*

6-6 Alarm Service. Alarm service, if provided, shall comply with NFPA 72, *National Fire Alarm Code.*

Chapter 7 Training and Procedures

7-1 Employee Training. The requirements of 7-1.1 through 7-1.3 shall be applied retroactively.

7-1.1 Operating and maintenance procedures and emergency plans shall be developed. These shall be reviewed annually, and as required by process changes.

7-1.2 Initial and refresher training shall be provided to employees involved in operating, maintaining, and supervising facilities handling combustible particulate solids.

7-1.3 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 Inspection and Maintenance

8-1 Inspection and Maintenance. The requirements of 8-1.1 through 8-1.3 shall be applied retroactively.

8-1.1 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.

8-1.2 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

8-1.3 Records shall be kept of maintenance and repairs performed in accordance with 8-1.2.

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 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 10, *Standard for Portable Fire Extinguishers,* 1994 edition.

NFPA 11, *Standard for Low-Expansion Foam,* 1994 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems,* 1994 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 1993 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 1997 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 1996 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose 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,* 1994 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* 1995 edition.

NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products,* 1994 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 80, *Standard for Fire Doors and Fire Windows,* 1995 edition.

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

NFPA *101®, Life Safety Code®,* 1997 edition.

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

NFPA 220, *Standard on Types of Building Construction,* 1995 edition.

NFPA 221, *Standard for Fire Walls and Fire Barrier Walls,* 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 485, *Standard for the Storage, Handling, Processing, and Use of Lithium Metal,* 1994 edition.

NFPA 495, *Explosive Material Code,* 1996 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment,* 1993 edition.

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

NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials,* 1990 edition.

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

NFPA 655, *Standard for 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 1124, *Code for the Manufacture, Transportation, and Storage of Fireworks,* 1995 edition.

NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors,* 1995 edition.

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

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

Appendix A Explanatory Material

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

A-1-1.1 Examples of industries that handle combustible particulate solids, either as a process material or as a fugitive or nuisance dust, include but are not limited to agricultural, chemical, and food commodities, fibers, and textile materials; forest and furniture products industries; metals processing; paper products; pharmaceuticals; resource recovery operations (tires, municipal solid waste, metal, paper, or plastic recycling operations); and wood, metal, or plastic fabricators.

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 the following four requirements:

(a) A combustible dust

(b) A dust dispersion in air or other oxidant at or exceeding the minimum explosible 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. Each situation should be evaluated and applicable tests selected. The following list represents the factors that are sometimes used in determining the deflagration hazard of a dust:

(a) Minimum explosible concentration (MEC)

(b) Minimum ignition energy (MIE)

(c) Particle size distribution

(d) Moisture content as received and as tested

(e) Maximum explosion pressure at optimum concentration

(f) Maximum rate of pressure rise at optimum concentration

(g) K_{St} (normalized rate of pressure rise) as defined in ASTM E 1226, *Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts*

(h) Layer ignition temperature

(i) Dust cloud ignition temperature

(j) Limiting oxidant concentration (LOC) to prevent ignition

(k) Electrical volume resistivity

(l) Charge relaxation time

(m) Chargeability

A-1-5 Combustible Particulate Solid. This term addresses the attrition of the material as it moves within the process equipment. Particle abrasion breaks the material down and produces a mixture of large and small particulates, some of which might be small enough to be classified as dusts. Consequently, the presence of dusts should be anticipated in the process stream, regardless of the starting particle size of the material.

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 minimum explosible concentration (MEC), and the vapor 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 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 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 MEC is dependent upon 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.

A-2-1.3 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 and instrumentation diagrams.

A-2-3.2 Window ledges, girders, beams, and other horizontal projections or surfaces can have the tops sharply sloped, or other provisions can be made to minimize the deposit of dust thereon. Overhead steel I-beams or similar structural shapes can be boxed with concrete or other noncombustible material to eliminate surfaces for dust accumulation. Surfaces should be as smooth as possible to minimize dust accumulations and to facilitate cleaning.

A-2-3.9 The use of load-bearing walls should be avoided to prevent structural collapse should an explosion occur.

A-2-4 The design of deflagration venting should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations.*

A-2-4.1 The need for building deflagration venting is a function of equipment design, particle size, deflagration characteristics of the dust, and housekeeping. As a rule, deflagration venting is recommended unless it can be reasonably assured that hazardous quantities of combustible and dispersible dusts will not be permitted to accumulate outside of equipment.

Where building explosion venting is needed, detaching the operation to an open structure or to a building of damage-limiting construction are the preferred methods of protection. Damage-limiting construction involves a room or building designed such that certain interior walls are pressure resistant (can withstand the pressure of the deflagration) to protect the occupancy on the other side, and some exterior wall areas are pressure relieving to provide deflagration venting. It is preferable to make maximum use of exterior walls as pressure-relieving walls (as well as the roof wherever practical), rather than provide the minimum recommended. Further information on this subject can be found in NFPA 68, *Guide for Venting of Deflagrations.*

Deflagration vent closures should be designed such that, once opened, they will remain open to prevent failure from the vacuum following the pressure wave.

A-2-4.2 For further information on restraining vent closures, see NFPA 68, *Guide for Venting of Deflagrations.*

A-2-5 High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust.

A-2-7.2 Refer to NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

A-3-1 Exception. A means to determine protection requirements should be based on a risk evaluation, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. See the American Institute of Chemical Engineers' Center for Chemical Process Safety Book, *Guidelines for Hazard Evaluation Procedures,* 2nd edition, with Worked Examples.

The following items are areas of concern during the design and installation of process equipment:

(a) The elimination of friction by use of detectors for slipping belts, temperature supervision of moving or impacted surfaces, and so forth

(b) Pressure resistance or maximum pressure containment capability and pressure-relieving capabilities of the machinery or process equipment and the building or room

(c) The proper classification of electrical equipment for the area and condition

(d) Proper alignment and mounting to minimize or eliminate vibration and overheated bearings

(e) The use of electrically conductive belting, low speed belts, and short center drives as a means of reducing static electricity accumulation *(see Section 5-3*)*

(f) When power is transmitted to apparatus within the processing room by belt or chain, it should be encased in a practically dust-tight enclosure, constructed of substantial noncombustible material that should be maintained under positive air pressure. Where power is transmitted by means of shafts, these should pass through close-fitting shaft holes in walls or partitions.

A-3-1.1(b) Where deflagration venting is used, its design should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations.* For deflagration relief venting through ducts, consideration should be given to the reduction in deflagration venting efficiency caused by the ducts. The relief duct should be restricted to no more than 20 ft (6 m).

A-3-1.1(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-3-1.2 Methods of explosion protection using containment, venting, and suppression protect the specific process equipment on which they are installed. Flame fronts from a deflagration can propagate through connecting ductwork to other unprotected process equipment and to the building from outside process equipment. Figure A-3-1.2 shows an example of how this propagation might occur. Isolation techniques as shown in Figures A-3-1.2.1 (c) through (e) can be used to prevent the propagation of the deflagration by arresting the flame front.

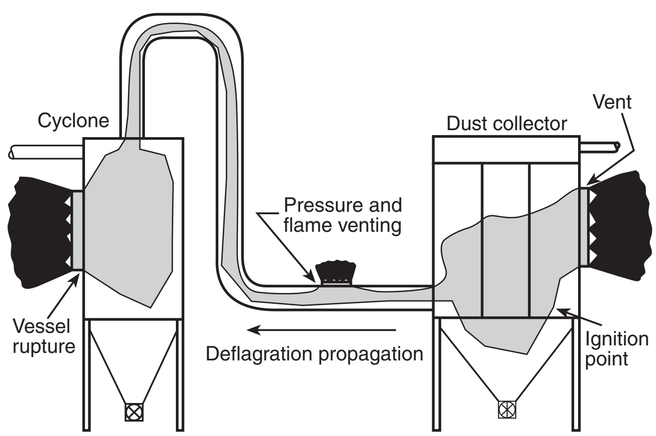

Figure A-3-1.2 An example of deflagration propagation without isolation.

A-3-1.2.1(a) Figure A-3-1.2.1(a) illustrates two different designs of chokes.

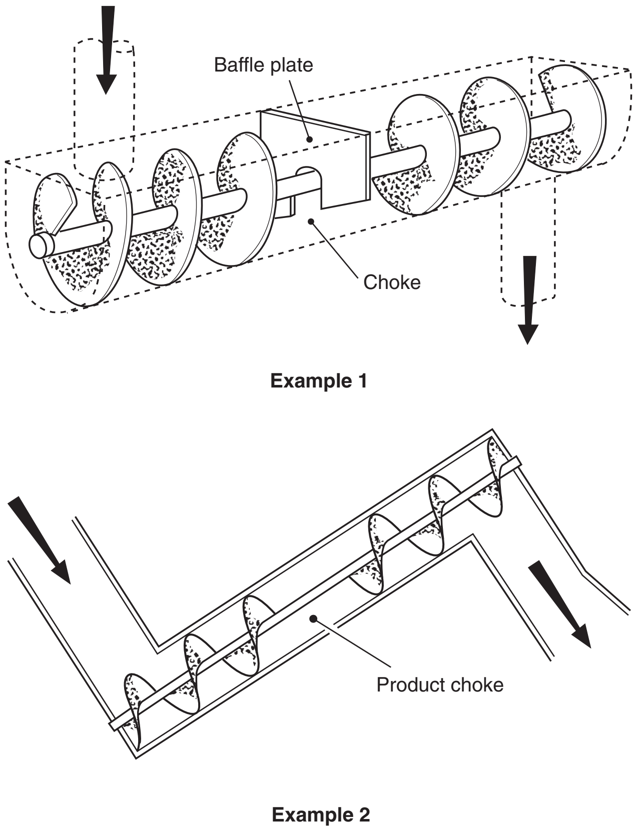

Figure A-3-1.2.1(a) Two examples of screw conveyor chokes.

A-3-1.2.1(b) When rotary valves are installed in both the inlet and outlet of equipment, care should be taken to ensure that the rotary valve on the inlet is stopped before the unit becomes overfilled. See Figure A-3-1.2.1(b).

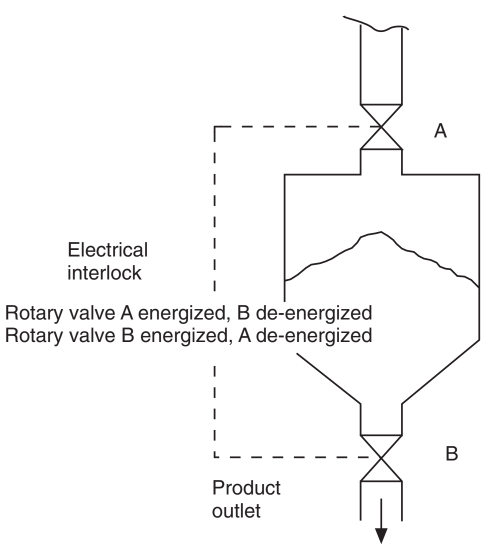

Figure A-3-1.2.1(b) An example of rotary valves.

A-3-1.2.1(c) Figure A-3-1.2.1(c) illustrates one example of deflagration propagation using mechanical isolation.

A-3-1.2.1(d) Figure A-3-1.2.1(d) illustrates one example of deflagration propagation using flame front diversion.

A-3-1.2.1(e) Figure A-3-1.2.1(e) illustrates one example of deflagration propagation using chemical isolation.

A-3-1.2.1 Exception No. 2. See A-3-1 Exception text for an explanation of the considerations of a documented risk evaluation.

A-3-1.2.2 Exposures of concern include, but are not limited to, bagging operations and hand dumping operations where the discharge of a fireball from the pickup point would endanger personnel.

A-3-2.4 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-3-2.5 For information on designing deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations.*

A-3-2.6 Exception No. 1. Small containers can pose an explosion hazard; however, explosion protection measures for these units are not always practical. Consideration should be given to explosion hazards when electing to omit protection.

A-3-2.6 Exception No. 2. Shipping containers can pose a deflagration hazard; however, deflagration protection measures for these units are not always practical. Consideration should be given to deflagration hazards when electing to omit deflagration protection.

A-3-3.1.1 Ducts for dust conveying systems should be as straight as possible; right angle bends should be avoided.

A-3-3.1.1(a) For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity.*

A-3-3.1.3 This can be accomplished by means of a concentric taper transformation piece, the included angle of the taper being not more than 30 degrees.

A-3-3.1.7 Isolation devices in accordance with 3-1.2* are provided to prevent deflagration propagation between connected equipment. In 3-3.1.7*, additional protection is indicated when the integrity of a physical barrier might be breached through ductwork failure caused by a deflagration outside the equipment. In some cases, a single equipment isolation device can provide protection in 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-3-3.2 It is recommended that bucket elevators be located outside of buildings wherever practical. While explosion protection for bucket elevators is required in 3-3.2.1, an additional degree of protection to building occupants and contents is provided by locating the bucket elevator outside of the building.

A-3-3.2.1 Deflagration vents on bucket elevators should be distributed along the casing by providing deflagration vents in pairs opposite each other located on the casing side next to the ends of the buckets. Each deflagration vent should be a minimum of two-thirds of the cross-sectional area of the leg casing and should be located approximately 20 ft (6 m) apart.

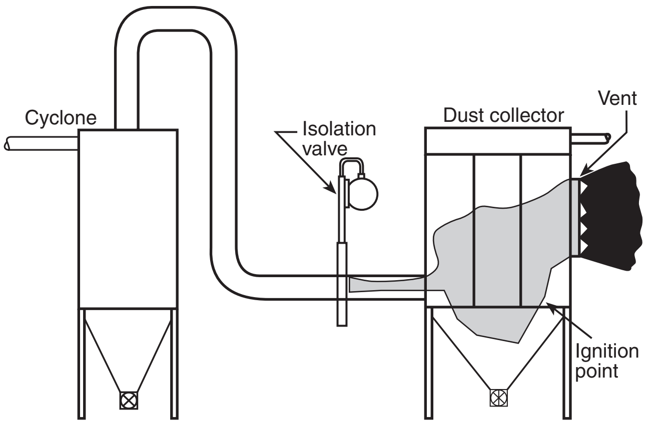

Figure A-3-1.2.1(c) An example of deflagration propagation with mechanical isolation.

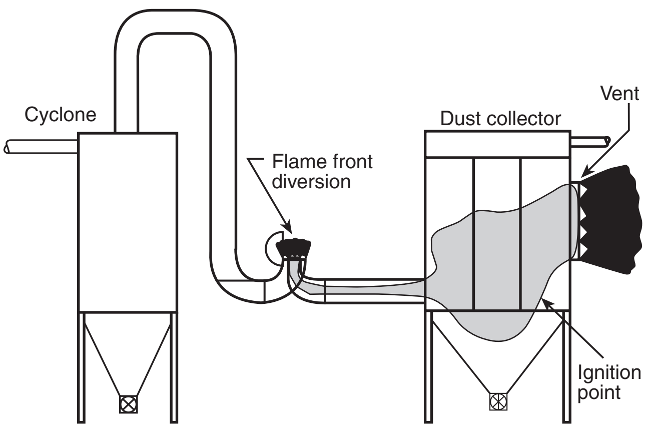

Figure A-3-1.2.1(d) An example of deflagration propagation with flame front diversion.

Vent closures should be designed to open at an internal pressure of 0.5 psig to 1.0 psig (gauge pressures of 3.4 kPa to 6.9 kPa). Vent closure devices should be secured to eliminate the possibility of the closures becoming missiles. Vent materials should be of lightweight construction and meet the guidelines given in NFPA 68, *Guide for Venting of Deflagrations.*

Bucket elevator head sections are recommended to have 5 ft^2 (0.5 m^2) of vent area for each 100 ft^3 (2.8 m^3) of head section volume.

Vents should not be directed at work platforms, building openings, or other potentially occupied areas.

For bucket elevators inside of buildings, vent ducts should be designed with a cross-sectional area at least as large as the vent, should be structurally as strong as the bucket elevator casing, and should be limited in length to 10 ft (3 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 practical.

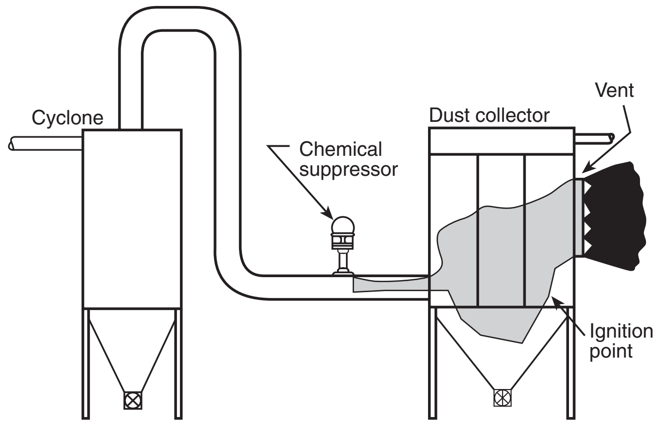

Figure A-3-1.2.1(e) An example of deflagration propagation with chemical isolation.

A-3-3.2.7 Where it is desired to prevent propagation of an explosion from the elevator leg to another part of the facility, an explosion isolation system should be provided at the head, boot, or at both locations.

A-3-3.2.8 The motor selected should not be larger than the smallest standard motor capable of meeting this requirement.

A-3-3.3 Explosion protection should be provided when the risk is significant. (*See 3-1.1.*)

A-3-3.3.2 Some chemical and plastic dusts release residual flammable vapors such as residual solvents, monomers, or resin additives. These vapors can be released from the material during handling or storage. Design of the system should be based on a minimum airflow sufficient to keep the concentration of the particular flammable vapor in the airstream below 25 percent of the lower flammable limit of the vapor.

A-3-3.4.1 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 pneumatic conveying systems.

A threshold concentration limit approximately equal to 1 percent of the MEC for a typical combustible dust or 1 percent of the LFL of a typical hydrocarbon in grams per m^3 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 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 3-3.4.1, Exception No. 2 (b), provisions 1– 7

A-3-3.4.1 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-3-7.2 Heating by indirect means is less hazardous than by direct means and is therefore preferred. Improved protection can be provided for direct-fired dryers by providing an approved automatic spark detection and extinguishing system.

A-3-7.10 The maximum safe operating temperature of a dryer is a function of the time-temperature ignition characteristics of the particulate solid being dried as well as the dryer type. For short-time exposures of the material to the heating zone, the operating temperatures of the dryer can approach the dust cloud ignition temperature.

However, if particulate solids accumulate on the dryer surfaces, the operating temperature should be maintained below the dust layer ignition temperature. The dust layer ignition temperature is a function of time, temperature, and thickness of the layer. It can be several hundred degrees below the dust cloud ignition temperature.

The operating temperature limit of the dryer should be based on an engineering evaluation, taking into consideration the above factors.

The dust cloud ignition temperature can be determined by the method referenced in the U.S. Bureau of Mines, Report of Investigations, RI 8798, "Thermal and Electrical Ignitability of Dusts," Conti, R. S., Cashdollar, K. L., Hertzberg, M., Liebman, I., 1983 (modified Godbert-Greenwald furnace), the BAM Furnace, or other methods. The dust layer ignition temperature can be determined by Bureau of Mines test procedure in *Fire and Materials Journal,* Lazzara, C. and Miron, Y., "Hot Surface Ignition Temperatures of Dust Layers," vol. 12, pp. 115–126, June 1988.

A-4-1.2 Exception No. 2. Where deflagration venting is used, its design should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations.* For deflagration relief venting through ducts, consideration should be given to the reduction in deflagration venting efficiency caused by the ducts. The ducts should be designed with a cross-sectional area at least as large as the vent, should be structurally as strong as the dust collector, 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 practical.

A-4-2.1 A relatively small initial dust deflagration can 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 deflagration, which can cause damage. Reducing significant additional dust accumulations is, therefore, a major factor in reducing the hazard in areas where a dust hazard can exist.

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 averaging $^1/_{32}$ 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 dispersed completely 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 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 above information, 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 (1860 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 also be given to other projections such as light fixtures, which can provide surfaces for dust accumulation.

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

Guidelines (a) through (g) will serve to establish a cleaning frequency.

A-4-2.2 Vacuum cleaning systems are preferred for this purpose.

A-5-1.1 See Figures A-5-1.1(a) and (b) for examples of foreign material removal.

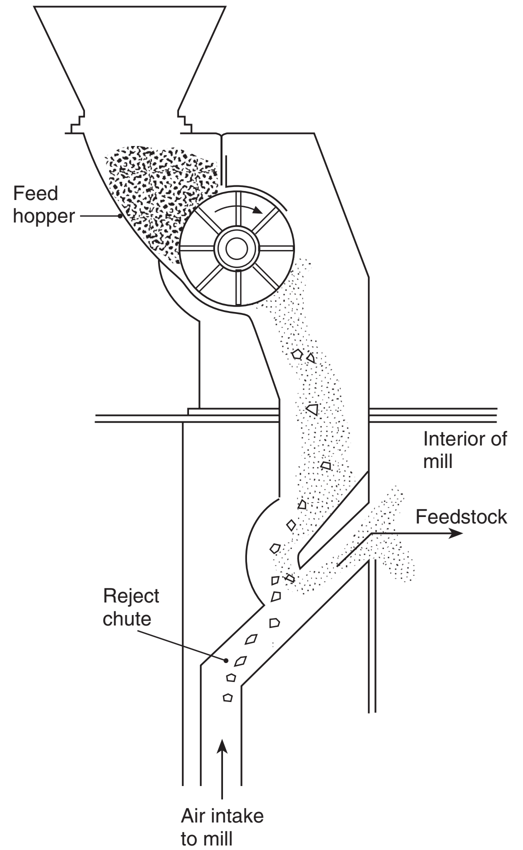

Figure A-5-1.1(a) An example of a pneumatic separator.

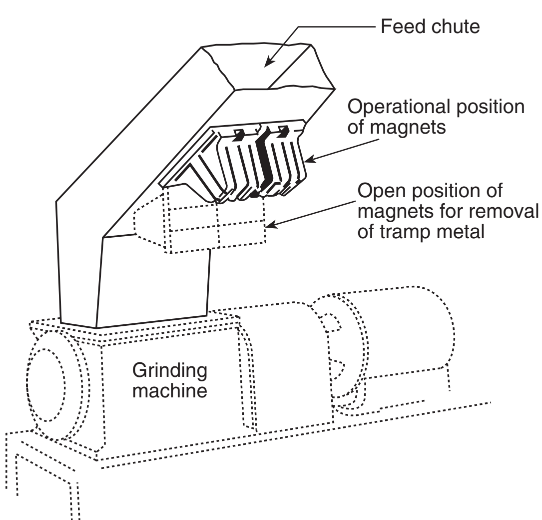

Figure A-5-1.1(b) An example of a magnetic separator.

A-5-1.2 Transmission of power by direct drive should be used, where possible, in preference to belt or chain drives.

A-5-1.3 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-5-3 See NFPA 77, *Recommended Practice on Static Electricity,* for information on this subject.

A-5-3.1 Bonding minimizes the potential difference between conductive objects. Grounding minimizes the potential difference between objects and ground.

A-5-3.3 Exception. Certain fabrics for use in FIBCs, have been developed that pose significantly less risk of ignition in flammable atmospheres. One such fabric that has been tested for use in atmospheres having a minimum ignition energy of 0.25 mJ or greater, and has been used in FIBCs is documented in the following paper by V. Ebadat and J. C. Mulligan, "Testing the Suitability of FIBCs for Use in Flammable Atmospheres," 30th Annual Loss Prevention Symposium, AIChE, 1996 Spring National Meeting, New Orleans, LA, February 1996.

A-5-7.1 The ignition temperature of a layer of dust on hot surfaces might decrease over time if the dust dehydrates or carbonizes. For this reason, the hot surfaces should not exceed the lower of either the ignition temperature or 165°C. The ignition temperatures for many materials are shown in NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

A-6-1 Pneumatic conveying systems that move combustible particulate solids can be classified as water-compatible, water-incompatible, or water-reactive. Inasmuch as water is the universally 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 materials:

(a) Wood dusts, fibers, chips, shavings, and flakes

(b) Some paper dusts depending upon 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 in which 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 in which 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 materials:

(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 materials, 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, mono-ammonium phosphate, nitrogen, and clean agents. However, a water-based extinguishing system can be employed as a backup to the special agent extinguishing systems.

Examples of water-incompatible systems include water-soluble materials and 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 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 handled with care, as their reactivity is highly dependent on the particular metal, particle size, and temperature.

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

Handling the material in an inerted system is often used because of the difficulties encountered in extinguishing these materials. However, it should be noted that some commonly considered inerting agents, such as CO_2 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, 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-6-4 Automatic sprinkler protection within dust collectors, silos, and bucket elevators should be considered. Considerations should include the combustibility of the equipment, the combustibility of the material, and the amount of material present.

A-6-4.1 A risk evaluation should consider the presence of combustibles both in the equipment and the area around the process. Considerations should include the combustibility of the building construction, equipment, the quantity and combustibility of process materials, packaging materials, open containers of flammable liquids, and presence of dusts. Automatic sprinkler protection within dust collectors, silos, and bucket elevators should be considered.

A-7-1.3(g) All plant personnel, including management, supervisors, and maintenance and operating personnel, should be trained to participate in plans for controlling plant emergencies. Trained plant fire squads or fire brigades should be maintained.

The emergency plan should contain the following elements:

(a) A signal or alarm systems

(b) Identification of means of egress

(c) Minimized effect on operating personnel and the community

(d) Minimized property and equipment losses

(e) Interdepartmental and interplant cooperation

(f) Cooperation of outside agencies

(g) The release of accurate information to the public

Simulated emergency drills should be performed annually by plant personnel. Malfunctions of the process should be simulated and emergency actions undertaken. "Disaster" drills that simulate a major catastrophe situation should be undertaken periodically with the cooperation and participation of public fire, police, and other local community emergency units and nearby cooperating plants.

A-8-1.2(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."

Appendix B Additional Information on Explosion Protection

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

This section covers the following common methods of explosion protection:

- Containment
- Inerting
- Deflagration venting
- Deflagration suppression
- Deflagration isolation

B-1 Containment. The basis for this method of protection is designing the process to withstand the maximum deflagration pressure of the material being handled. The equipment is designed in accordance with ASME *Boiler and Pressure Vessel Code,* Section VIII, Division 1. It is important to note that the final deformation pressure will be dependent upon the maximum initial pressure within the vessel prior to the deflagration. NFPA 69, *Standard on Explosion Prevention Systems,* limits this maximum initial pressure to 30 psig (gauge pressure of 207 kPa) for containment vessels.

The equipment is either designed to prevent permanent deformation (working below its yield strength), or designed not to rupture, with some permanent deformation allowable (working above its yield strength but below its ultimate strength). The shape of the vessel should be considered. To maximize the strength of the vessel, the vessel design should avoid flat surfaces and rectangular shapes. The strength of welds and other fastenings should also be considered.

The following is an advantage of containment:

- Low maintenance — passive

The following are disadvantages of containment:

- High initial cost
- Weight loading on plant structure

B-2 Inerting. Protection is provided by lowering the oxygen concentration, in an enclosed volume, to below the level required for combustion. This is achieved by the introduction of an inert gas such as nitrogen or carbon dioxide. Flue gases might also be used, but might first require cleaning and cooling. *(See NFPA 69, Standard on Explosion Prevention Systems.)*

The purge gas flow and oxygen concentration within the process should be designed reliably with appropriate safety factors in accordance with NFPA 69 . Consideration should be given to the potential hazard to personnel by asphyxiation due to leakage of purge gas.

The following is an advantage of inerting:

- Prevention of combustion, thereby avoiding product loss

The following are disadvantages of inerting:

- Ongoing cost of inert gas
- Possible personnel asphyxiation hazard
- High maintenance

B-3 Deflagration Venting. With deflagration venting, a panel or door (vent closure) is provided to relieve the expanding hot gases of a deflagration from within a process component or room.

B-3.1 How Deflagration Venting Works. Except for an open vent, which allows flammable gases to discharge directly to atmosphere, deflagration vents open at a predetermined pressure referred to as P_{stat}. The vent is either a vent panel or a vent door. The pressurized gases are discharged to atmosphere either directly or via a vent duct. This results in a reduced deflagration pressure, P_{red}. The deflagration vent arrangement is designed to ensure that pressure, P_{red}, is below the rupture pressure of the process vessel or room. This is illustrated in Figure B-3.1.

B-3.2 Deflagration Vent Panel. This is a flat or slightly domed panel that is bolted or otherwise attached to an opening on the process component to be protected. The panel can be made of any material and construction that will allow the panel to either rupture, detach, or swing open from the protected volume; materials that could fragment and act as shrapnel should not be used. Flat vents might require a vacuum support arrangement or a support against high winds. Domed vents are designed to have a greater resistance against wind pressure, process cycles, and process vacuums. A typical commercially available vent panel is detailed in Figure B-3.2. These vents are either rectangular or circular.

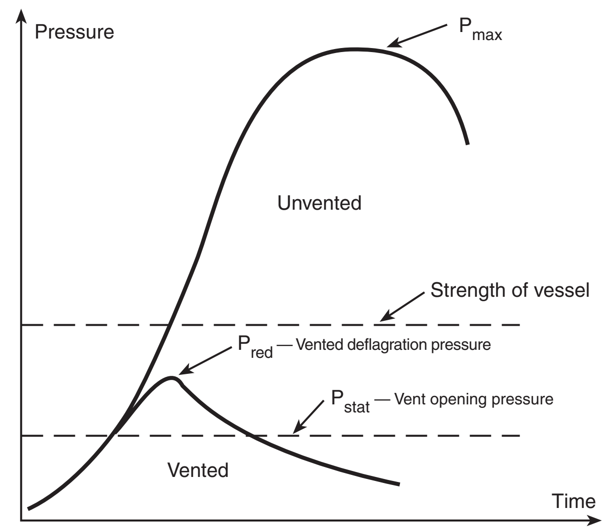

Figure B-3.1 Pressure-time graph of a vented deflagration.

B-3.3 Deflagration Vent Door. A deflagration vent door is a hinged door mounted on the process component to be protected. It is designed to open at a predetermined pressure that is governed by a special latch arrangement. Generally, vent doors have a greater inertia than a vent panel. This reduces their efficiency.

B-3.4 Applications. Deflagration vents are used for applications handling gases, dusts, or hybrid mixtures. Typical applications include dust collectors, silos, spray dryers, bucket elevators, and mixers. Figure B-3.4 shows a typical vent panel installation on a dust collector.

The following are advantages of deflagration venting:

- Low cost if the process component is located outside
- Low maintenance — passive device

The following are disadvantages of deflagration venting:

- Potential for a post-venting fire within the component, particularly if there are combustible materials, such as filter bags, still present
- Plant component should be near an outside wall or located outside
- Fireball exiting a vented component, which is a severe fire hazard to the plant and personnel located in the vicinity of the deflagration vent opening
- Not recommended for toxic or corrosive material

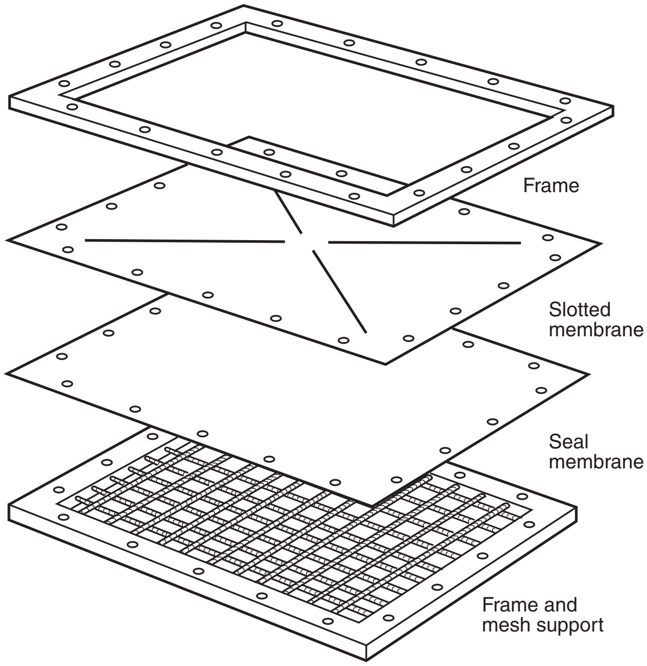

Figure B-3.2 Deflagration vent panel and support grid.

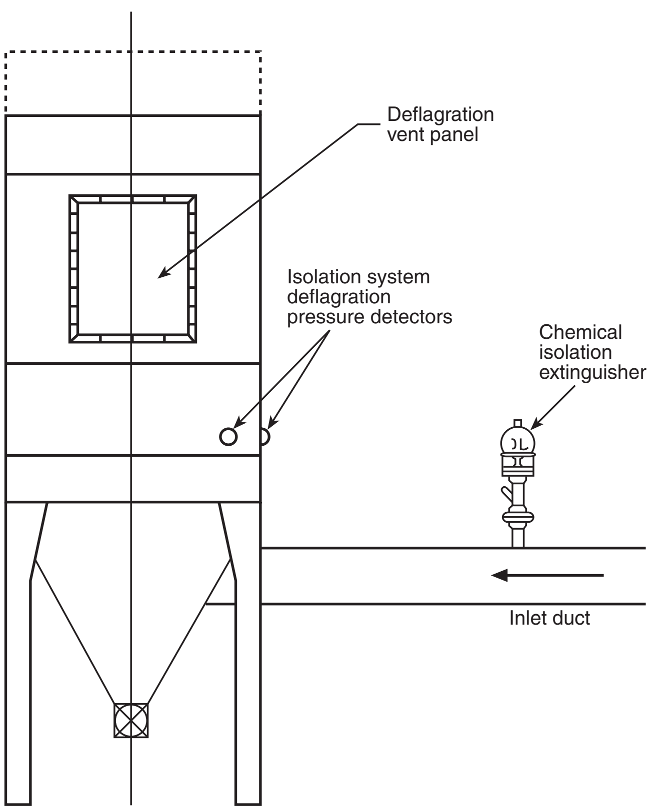

Figure B-3.4 An example of a vented dust collector.

B-3.5 Design Considerations. The following points should be considered when designing and evaluating the suitability of deflagration venting:

- Reaction forces
- Post-explosion fires
- Material toxicity or corrosiveness
- Good Manufacturing Practices (GMP) (food and pharmaceutical applications)
- Vent efficiency
- Connections to other process equipment
- Vent duct back pressure
- Thermal insulation
- Safe venting area
- Vacuum protection
- Location

B-4 Deflagration Suppression. This involves a high-speed flame extinguishing system that detects and extinguishes a deflagration before destructive pressures are created.

B-4.1 How Deflagration Suppression Works. An explosion is not an instantaneous event. There is a measurable time for the growing fireball to create its destructive pressures. Typically the fireball expands at speeds of 30 ft per sec (9 m per sec). In contrast, the pressure wave ahead of it travels at 1100 ft per sec (335 m per sec). The deflagration is detected either by a pressure detector or a flame detector. A signal passes to a control unit, which actuates one or several high-rate discharge extinguishers. The extinguishers are mounted directly on the process to be protected, rapidly suppressing the fireball. The whole process takes milliseconds. The sequence for deflagration suppression is shown in Figure B-4.1(a).

In suppressing the fireball at its early stage, rupture of the vessel is prevented. Figure B-4.1(b) shows the pressure-time graph of the suppression of a starch deflagration in a 1.9 m^3 (65 ft^3) vessel. Note that the reduced deflagration pressure is approximately 3.5 psig (gauge pressure of 24 kPa) in this test.

B-4.2 Applications. Deflagration suppression systems are used for applications handling gases, dusts, or hybrid mixtures. Typical applications include dust collectors, silos, spray dryers, bucket elevators, and mixers. Figure B-4.2 shows a typical suppression system installation on a dust collector.

The following are advantages of a deflagration suppression system:

- Eliminates flame and prevents subsequent fire
- Reduces risk of ejecting toxic or corrosive material
- Allows flexibility in process component locations

The following are disadvantages of a deflagration suppression system:

- Cost generally higher than deflagration venting
- Regular maintenance required
- Not effective for certain metal dusts, acetylene, and hydrogen.

B-4.3 Design Criteria. Deflagration suppression systems are designed in accordance with NFPA 69 and ISO 6184-4, *Explosion Protection Systems — Part 4: Determination of Efficiency of Explosion Suppression Systems.* The following information is required to design a suppression system:

- Process material
- K_{st} or K_g value in bar-m/second
- Vessel strength
- Vessel dimensions and volume
- Maximum and minimum operating pressures and temperatures
- Connections to other process equipment