NFPA 654

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

2006 Edition

NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471
An International Codes and Standards Organization

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NFPA 654

Standard for the

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

2006 Edition

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 NFPA at its June Association Technical Meeting held June 6–10, 2005, in Las Vegas, NV. It was issued by the Standards Council on July 29, 2005, with an effective date of August 18, 2005, and supersedes all previous editions.

This edition of NFPA 654 was approved as an American National Standard on August 18, 2005.

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 prepared a complete revision for the 1982 edition, the scope of which was expanded to include chemical, dye, and pharmaceutical dusts, since the fire and explosion hazards of those dusts are generally the same as for plastic dusts.

In 1988, the committee voted to reconfirm the text as it appeared in the 1982 version, with minor editorial corrections and changes in accordance with the NFPA *Manual of Style*.

In 1994, the standard was revised to improve its usability, adoptability, and enforceability; to update outdated terminology; and to add the NFPA language for equivalency and retroactivity.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 NFPA 69, *Standard on Explosion Prevention Systems*. The committee also clarified the requirements relating to controlling hazardous accumulations of process dust.

The 1997 edition was a complete revision that incorporated new processing and explosion protection technologies. The title of the document was revised to reflect that the standard encompassed 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.

A complete revision for the 2000 edition incorporated portions of NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Particulate Solids*, which was withdrawn in 2000. NFPA 654 retained its title and provided a unified approach for protecting facilities that handled most combustible particulate solids. The combination of documents eliminated the redundancy that previously had existed between the two, similar standards. The 2000 edition of NFPA 654 included specific requirements related to fire protection in addition to the existing explosion protection requirements.

The 2006 edition is another complete revision, which introduces a performance-based approach for protecting combustible particulate solids processing facilities. This new approach enables users of the standard to follow the traditional prescriptive method or, for unique situations, gives them the option of a performance-based design. Other changes include updating the standard to the current *Manual of Style for NFPA Technical Committee Documents* format.

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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.

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

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

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex G. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex G.

Chapter 1 Administration

1.1* Scope.

1.1.1 This standard shall apply to all phases of the manufacturing, processing, blending, pneumatic conveying, repackaging, and handling of combustible particulate solids or hybrid mixtures, regardless of concentration or particle size, where the materials present a fire or explosion hazard.

1.1.2 The owner/operator shall be responsible for implementing the requirements in this standard.

1.2 Purpose. The purpose of this standard is to prescribe technical requirements for safety to life and property from fire and explosion and to minimize the resulting damage from a fire or explosion.

1.3 Goal. The goal of this standard is to provide safety measures to prevent and mitigate fires and dust explosions in facilities that handle combustible particulate solids.

1.4 Application.

1.4.1 This standard shall not apply to materials covered by the following documents, unless specifically referenced by the applicable document:

(1) NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*
(2) NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*
(3) NFPA 85, *Boiler and Combustion Systems Hazards Code*
(4) NFPA 120, *Standard for Fire Prevention and Control in Coal Mines*
(5) NFPA 432, *Code for the Storage of Organic Peroxide Formulations*
(6) NFPA 484, *Standard for Combustible Metals*
(7) NFPA 495, *Explosive Materials Code*
(8) NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*
(9) NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*
(10) NFPA 1124, *Code for the Manufacture, Transportation, Storage, and Retail Sales of Fireworks and Pyrotechnic Articles*
(11) NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*

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

1.5 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.5.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.5.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.5.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.5.4 This standard shall apply to facilities on which construction is begun subsequent to the date of publication of the standard.

1.5.5 When major replacement or renovation of existing facilities is planned, provisions of this standard shall apply.

1.6 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.

1.6.1 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

1.6.2 The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

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Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 10, *Standard for Portable Fire Extinguishers,* 2002 edition.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2005 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2005 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 2004 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2002 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2003 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2001 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems,* 2003 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 2002 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2002 edition.

NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products,* 2002 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2003 edition.

NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities,* 2002 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 2002 edition.

NFPA 70, *National Electrical Code®,* 2005 edition.

NFPA 72®, National Fire Alarm Code®, 2002 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows,* 1999 edition.

NFPA 85, *Boiler and Combustion Systems Hazards Code,* 2004 edition.

NFPA 86, *Standard for Ovens and Furnaces,* 2003 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids,* 2004 edition.

NFPA *101®, Life Safety Code®,* 2006 edition.

NFPA 120, *Standard for Fire Prevention and Control in Coal Mines,* 2004 edition.

NFPA 220, *Standard on Types of Building Construction,* 2006 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls,* 2006 edition.

NFPA 432, *Code for the Storage of Organic Peroxide Formulations,* 2002 edition.

NFPA 484, *Standard for Combustible Metals,* 2006 edition.

NFPA 495, *Explosive Materials Code,* 2006 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment,* 2003 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations,* 2006 edition.

NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions,* 2001 edition.

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities,* 2002 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2003 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 2004 edition.

NFPA 1124, *Code for the Manufacture, Transportation, Storage, and Retail Sales of Fireworks and Pyrotechnic Articles,* 2006 edition.

NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors,* 2001 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2004 edition.

2.3 Other Publications.

2.3.1 ASME Publications. American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

ASME B31.3, *Process Piping,* 2002.

ASME Boiler and Pressure Vessel Code, 2001.

2.3.2 ISA Publication. Instrumentation, Systems, and Automation Society, P.O. Box 12277, Research Triangle Park, NC 27709.

ISA 84.00.01, *Functional Safety: Application of Safety Instrumented Systems for the Process Industry Sector,* 2004.

2.3.3 Other Publication. *Merriam-Webster's Collegiate Dictionary,* 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

NFPA 68, *Guide for Venting of Deflagrations,* 2002 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids,* 2004 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls,* 2006 edition.

NFPA 484, *Standard for Combustible Metals,* 2006 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary,* 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 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.

3.2.4* 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

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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 appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

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

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

3.3 General Definitions.

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

3.3.2* Air–Material Separator (AMS). A collector designed to separate the conveying air from the material being conveyed.

3.3.2.1 ***Primary Air–Material Separator.*** A collector that separates the bulk of the product or material from the conveying airstream.

3.3.2.2 ***Secondary Air–Material Separator.*** A collector that separates the residual dust or product remaining in the airstream after the airstream has been processed by the primary air–material separator.

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

3.3.4* Combustible Dust. A combustible particulate solid that presents a fire or deflagration hazard when suspended in air or some other oxidizing medium over a range of concentrations, regardless of particle size or shape.

3.3.5* Combustible Particulate Solid. Any combustible solid material, composed of distinct particles or pieces, regardless of size, shape, or chemical composition.

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

3.3.7* Deflagration. Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium. [**68,** 2002]

3.3.8 Detachment. Locating a combustible particulate solid process in the open air or in a separate building.

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

3.3.10 Duct. Pipes, tubes, or other enclosures used for the purpose of pneumatically conveying materials. [**91,** 2004]

3.3.11 Dust Collector. See 3.3.2, Air–Material Separator (AMS).

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

3.3.13* Hybrid Mixture. A mixture of a flammable gas with either a combustible dust or a combustible mist. [**68,** 2002]

3.3.14 Intermediate Bulk Containers.

3.3.14.1 ***Flexible Intermediate Bulk Container (FIBC).***

3.3.14.1.1 ***Type A FIBC.*** A standard insulating flexible intermediate bulk container (FIBC).

3.3.14.1.2 ***Type B FIBC.*** A flexible intermediate bulk container (FIBC) where the fabric or the combination of the fabric shell, coating, and any loose liner has a breakdown voltage of less than 6000 volts.

3.3.14.1.3 ***Type C FIBC.*** A flexible intermediate bulk container (FIBC) where the fabric is interwoven with an electrically interconnected conductive fiber and provided with a tab for connection to grounding systems.

3.3.14.1.4 ***Type D FIBC.*** A flexible intermediate bulk container (FIBC) constructed from fabric and/or threads with special static properties designed to control electrostatic discharge incendivity, without grounding.

3.3.14.2* ***Rigid Intermediate Bulk Container (RIBC).*** An intermediate bulk container (IBC) that can be enclosed in or encased by an outer structure consisting of a steel cage, a single-wall metal or plastic enclosure, or a double wall of foamed or solid plastic.

3.3.14.2.1 ***Insulating RIBC.*** An RIBC constructed entirely of solid plastic or solid plastic and foam composite that cannot be electrically grounded.

3.3.15* Lower Flammable Limit (LFL). The lowest concentration of material that will propagate a flame from an ignition source through a mixture of flammable gas or combustible dust dispersion with a gaseous oxidizer.

3.3.16* Minimum Explosible Concentration (MEC). The minimum concentration of a combustible dust suspended in air, measured in mass per unit volume, that will support a deflagration.

3.3.17* Noncombustible Material. A material that, in the form in which it is used and under the conditions anticipated, will not ignite, support combustion, burn, or release flammable vapors when subjected to fire or heat.

3.3.18 Owner/Operator. The organization with fiscal responsibility for the operation, maintenance, and profitability of the facility.

3.3.19* Pneumatic Conveying System. A material feeder, an air–material separator, an enclosed ductwork system, or an air-moving device in which a combustible particulate solid is conveyed from one point to another with a stream of air or other gases.

3.3.19.1* ***Negative-Pressure Pneumatic Conveying System.*** A pneumatic conveying system that transports material by utilizing gas at less than atmospheric pressure.

3.3.19.2* ***Positive-Pressure Pneumatic Conveying System.*** A pneumatic conveying system that transports material by utilizing gas at greater than atmospheric pressure.

3.3.20 Replacement-in-Kind. A replacement that satisfies the design specifications. [**484,** 2006]

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

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

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

3.3.24 Vent Closure. A pressure-relieving cover that is placed over a vent. [**68,** 2002]

3.3.25 Vented Explosion Pressure (P_{red}). The maximum pressure developed in a vented enclosure during a vented deflagration.

3.3.26 Wall.

3.3.26.1 ***Fire Barrier Wall.*** A wall, other than a fire wall, having a fire resistance rating. [**221,** 2006]

3.3.26.2 ***Fire Wall.*** A wall separating buildings or subdividing a building to prevent the spread of fire and having a fire resistance rating and structural stability. [**221,** 2006]

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

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

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

Chapter 4 General Requirements

4.1 Process and Facility Design.

4.1.1 The design of processes and facilities that handle combustible particulate solids shall consider the physical and chemical properties that establish the hazardous characteristics of the materials.

4.1.2* The design and its basis shall be documented and maintained for the life of the process.

4.2 Process Hazard Analysis.

4.2.1* The design of the fire and explosion safety provisions shall be based on a process hazard analysis of the facility, the process, and the associated fire or explosion hazards.

4.2.2 The results of the process hazard analysis shall be documented and maintained for the life of the process.

4.2.3 The process hazard analysis shall be reviewed and updated at least every 5 years.

4.3 Management of Change. Written procedures to manage change to process materials, technology, equipment, procedures, and facilities shall be established and implemented.

4.3.1 The requirements of 4.3.1.1 through 4.3.1.3 shall be applied retroactively.

4.3.1.1 The management-of-change procedures shall ensure that the following issues are addressed prior to any change:

(1) The technical basis for the proposed change
(2) The safety and health implications
(3) Whether the change is permanent or temporary
(4) Modifications to operating and maintenance procedures
(5) Employee training requirements
(6) Authorization requirements for the proposed change

4.3.1.2 Implementation of the management-of-change procedures shall not be required for replacements-in-kind.

4.3.1.3 Design documentation, as required by 4.1.2, shall be updated to incorporate the change.

4.4* Pneumatic Conveying System Design. Systems that handle combustible particulate solids shall be designed by and installed under the supervision of qualified engineers who are knowledgeable about these systems and their associated hazards.

4.5 Objectives.

4.5.1 Life Safety.

4.5.1.1 The facility, combustible particulate processes, and human element programs shall be designed, constructed, equipped, and maintained to protect occupants not in the immediate proximity of the ignition from the effects of fire, deflagration, and explosion for the time needed to evacuate, relocate, or take refuge.

4.5.1.2 The structure shall be located, designed, constructed, and maintained to minimize the propagation of fire or explosion to adjacent properties and to avoid injury to the public.

4.5.2 Structural Integrity. The facility shall be designed, constructed, and equipped to maintain its structural integrity in spite of the effects of fire or explosion for the time necessary to evacuate, relocate, or defend in place occupants not in the immediate proximity of the ignition.

4.5.3* Mission Continuity. The facility, processes and equipment, and human element program shall be designed, constructed, equipped, and maintained to limit damage to levels that ensure the ongoing mission, production, or operating capability of the facility to a degree acceptable to the owner/operator.

4.5.4 Mitigation of Fire Spread and Explosions. The facility and processes shall be designed to prevent fires and explosions that can cause failure of adjacent compartments, emergency life safety systems, adjacent properties, adjacent storage, or the facility's structural elements.

4.5.4.1* The structure shall be designed, constructed, and maintained to prevent fire or explosions from causing failure of load-bearing structural members, propagating into adjacent interior compartments, and incapacitating fire protective and emergency life safety systems in adjacent compartments.

4.5.4.2 The structure shall be located, designed, constructed, equipped, and maintained to prevent the propagation of fire or explosion to or from adjacent storage or structures.

4.6* Compliance Options. The goal in Section 1.3 and the objectives in Section 4.5 shall be achieved by either of the following means:

(1) The prescriptive provisions in accordance with Chapters 6 through 12 of this standard
(2) The performance-based provisions in accordance with Chapters 5, 8, 9, 11, and 12 of this standard

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Chapter 5 Performance-Based Design Option

5.1 General Requirements.

5.1.1 Approved Qualifications. The performance-based design shall be prepared by a person with qualifications acceptable to the owner/operator.

5.1.2 Independent Review. The authority having jurisdiction shall be permitted to obtain an independent third party review of the proposed design.

5.1.3* Performance-based designs shall be documented with all calculations, references, assumptions, and sources from which material characteristics and other data have been obtained or on which the designer has relied for some material aspect of the design per Chapter 5 of NFPA *101*, *Life Safety Code*.

5.1.3.1 A sensitivity analysis shall be performed for each assumption that is not provided in an authoritative reference acceptable to the authority having jurisdiction to show that variation of said assumption does not result in a failure to meet design criteria.

5.1.3.2 The source of all calculation methods and models shall be documented with their limits of applicability.

5.1.4* Performance-based designs and documentation shall be updated and subject to re-approval if any of the assumptions on which the original design was based are changed.

5.1.5 Sources of Data.

5.1.5.1 Data sources shall be identified and documented for each input data requirement that must be met using a source other than a design fire scenario, an assumption, or a building design specification.

5.1.5.2 The degree of conservatism reflected in such data shall be specified, and a justification for the sources shall be provided.

5.2 Performance Criteria. A system and facility design shall be deemed to meet the objectives specified in Section 4.5 if its performance meets the criteria in 5.2.1 through 5.2.5.

5.2.1 Occupant Life Safety.

5.2.1.1 The life safety objectives of 4.5.1 with respect to a fire hazard shall be achieved if either of the following criteria is met:

(1) Ignition has been prevented.
(2) Under all fire scenarios, no person, other than those in the immediate proximity of the ignition, is exposed to untenable conditions due to the fire, and no critical structural element of the building is damaged to the extent that it can no longer support its design load during the period of time necessary to effect complete evacuation of the occupants.

5.2.1.2 The life safety objectives of 4.5.1 with respect to a explosion hazard shall be achieved if either of the following criteria is met:

(1) Ignition has been prevented.
(2) Under all explosion scenarios, no person, other than those in the immediate proximity of the ignition, is exposed to untenable conditions, including missile impact or overpressure, due to the occurrence of an explosion, and no critical structural element of the building is damaged to the extent that it can no longer support its design load during the period of time necessary to effect complete evacuation of the occupants.

5.2.2 Structural Integrity. The structural integrity objective of 4.5.2 with respect to fire and explosion shall be achieved when no critical structural element of the building is damaged to the extent that it can no longer support its design load under all fire and explosion scenarios.

5.2.3 Mission Continuity. The mission continuity objectives of 4.5.3 shall be achieved when damage to equipment and the facility has been limited to a level of damage acceptable to the owner/operator.

5.2.4 Mitigation of Fire Spread and Explosions. When limitation of fire spread is to be achieved, all of the following criteria shall be demonstrated:

(1) Adjacent combustibles shall not attain their ignition temperature.
(2) Building design and housekeeping shall prevent combustibles from accumulating exterior to the enclosed process system to a concentration that is capable of supporting propagation.
(3) Particulate processing systems shall prevent fire or explosion from propagating from one process system to an adjacent process system or to the building interior.

5.2.5 Effects of Explosions. Where the prevention of damage due to explosion is to be achieved, deflagrations shall not produce any of the following conditions:

(1) Internal pressures in the room or equipment sufficient to threaten its structural integrity
(2) Extension of the flame front outside the compartment or equipment of origin except where intentionally vented to a safe location
(3)*Rupture of the compartment or equipment of origin and the ejection of fragments that can constitute missile hazards

5.3* Design Scenarios.

5.3.1 Fire Scenarios.

5.3.1.1 Each fuel object in the compartment shall be considered for inclusion as a fire scenario.

5.3.1.2 The fuel object that produces the most rapidly developing fire during startup, normal operating conditions, or shutdown shall be included as a fire scenario.

5.3.1.3 The fuel object that produces the most rapidly developing fire under conditions of a production upset or single equipment failure shall be included as a fire scenario.

5.3.1.4 The fuel object that produces the greatest total heat release during startup, normal operating conditions, or shutdown shall be included as a fire scenario.

5.3.1.5 The fuel object that produces the greatest total heat release under conditions of a production upset or single equipment failure shall be included as a fire scenario.

5.3.1.6 The fuel object that can produce a deep-seated fire during startup, normal operating conditions, or shutdown shall be included as a fire scenario.

5.3.1.7 The fuel object that can produce a deep-seated fire under conditions of a production upset or single equipment failure shall be included as a fire scenario.

5.3.2 Explosion Scenarios.

5.3.2.1 Each duct, enclosed conveyor, silo, bunker, cyclone, dust collector, or other vessel containing a combustible dust in sufficient quantity or conditions to support the propagation of

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a flame front during startup, normal operating conditions, or shutdown shall be included as an explosion scenario.

5.3.2.2 Each duct, enclosed conveyor, silo, bunker, cyclone, dust collector, or other vessel containing a combustible dust in sufficient quantity or conditions to support the propagation of a flame front under conditions of production upset or single equipment failure shall be included as an explosion scenario.

5.3.2.3 Each building or building compartment containing a combustible dust in sufficient quantity or conditions to support the propagation of a flame front during startup, normal operating conditions, or shutdown shall be included as an explosion scenario.

5.3.2.4 Each building or building compartment containing a combustible dust in sufficient quantity or conditions to support the propagation of a flame front under conditions of production upset or single equipment failure shall be included as an explosion scenario.

5.4 Evaluation of Proposed Design.

5.4.1* General. A proposed design's performance shall be assessed relative to each performance objective in Section 4.5 and each applicable scenario in Section 5.3, with the assessment conducted through the use of appropriate calculation methods acceptable to the authority having jurisdiction.

5.4.2 The design professional shall establish numerical performance criteria for each of the objectives in Section 4.5.

5.4.3 The design professional shall use the assessment methods to demonstrate that the proposed design will achieve the goals and objectives, as measured by the performance criteria in light of the safety margins and uncertainty analysis, for each scenario, given the assumptions.

Chapter 6 Facility and Systems Design

6.1 General. The provisions of this section shall apply to the overall design of systems that handle combustible particulate solids.

6.1.1* Those portions of the process and facility where a dust deflagration hazard exists shall be protected from the effects of dust deflagrations in accordance with Sections 6.2, 6.3, and 6.4 and Chapter 7.

6.1.2 Those portions of the process and facility where a combustible particulate solid presents a fire hazard shall be protected in accordance with Chapter 10.

6.1.3 Recycling of Air–Material Separator Exhaust. Recycling of air–material separator exhaust to buildings shall be permitted if the system is designed to prevent both return of dust with an efficiency of 99.9 percent at 10 μm and transmission of energy from a fire or explosion to the building.

6.1.3.1 Recycling of air–material separator exhaust to the building shall not be permitted under any circumstances when combustible gases or vapors or hybrid mixtures are involved.

6.1.3.2* Recycling of air–material separator exhaust to the building shall not be permitted when the recycled stream reduces the concentration of oxygen below 19.5 percent by volume in the work area.

6.1.4 Extinguishing agents shall be compatible with the construction and process materials with which they could come into contact.

6.1.5* Where a pneumatic conveying system or any part of such systems operates as a positive-pressure-type system and the air-moving device's gauge discharge pressure is 15 psi (103 kPa) or greater, the system shall be designed in accordance with Section VIII of the *ASME Boiler and Pressure Vessel Code* or ASME B31.3, *Process Piping*.

6.1.6 All components of pneumatic conveying systems that handle combustible particulate solids shall be designed to be dusttight, except for openings designed for intake and discharge of air and material.

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

6.2.1 General. Areas in which combustible dusts are produced, processed, handled, or collected shall be detached, segregated, or separated from other occupancies to minimize damage from a fire or explosion.

6.2.2 Use of Segregation.

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

6.2.2.2 Physical barriers that are erected to segregate dust deflagration hazards shall be designed to preclude failure of those barriers before the deflagration pressure can be safely vented to the outside. *(For deflagration venting, see Section 6.4.)*

6.2.2.3 Doors and openings shall not be permitted in physical barriers unless they are normally closed and have the same strength as the physical barrier.

6.2.3 Use of Separation.

6.2.3.1* When separation is used to limit the fire or dust explosion hazardous area, the hazardous area shall include areas where dust accumulations exceed 1⁄32 in. (0.8 mm) or areas where dust clouds of a hazardous concentration exist, unless otherwise permitted by 6.2.3.3.

6.2.3.2 The requirements of 6.2.3.1 shall not apply to dust accumulations with a bulk density less than 75 lb/ft^3 (1200 kg/m^3), where the allowable thickness can be prorated upward by the following equation:

$$\textit{Allowable thickness}\ (\text{in.}) = \frac{(1/32)(75)}{\textit{bulk density}\ \left(\text{lb}/\text{ft}^3\right)}$$

6.2.3.3 Distance.

6.2.3.3.1 The required separation distance between the hazardous area identified in 6.2.3.1 and surrounding exposures shall be determined by the following:

(1) Engineering evaluation that addresses the properties of the materials
(2) Type of operation
(3) Amount of material likely to be present outside the process equipment
(4) Building design
(5) Nature of surrounding exposures

6.2.3.3.2 In no case shall the distance be less than 30 ft (9 m).

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6.2.3.4 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.

6.3 Building Construction.

6.3.1 All buildings shall be of Type I or Type II construction, as defined in NFPA 220, *Standard on Types of Building Construction*.

6.3.2 Where local, state, or national building codes are more restrictive, modifications shall be permitted for conformance to those codes.

6.3.3* Interior surfaces where dust accumulations can occur shall be designed and constructed so as to facilitate cleaning and to minimize combustible dust accumulations.

6.3.4 Spaces inaccessible to housekeeping shall be sealed to prevent dust accumulation.

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

6.3.6 Fire Doors.

6.3.6.1 Openings in fire walls and in fire barrier walls shall be protected by self-closing fire doors that have a fire resistance rating equivalent to the wall design.

6.3.6.2 Fire doors shall be installed according to NFPA 80, *Standard for Fire Doors and Fire Windows*, and shall normally be in the closed position.

6.3.7 Egress. Means of egress shall comply with NFPA *101*, *Life Safety Code*.

6.3.8 Penetrations. Where floors, walls, ceilings, and other partitions have been erected to control the spread of fire or deflagrations, penetrations in these structures shall be sealed to maintain their fire endurance rating and maintain physical integrity in a deflagration. *(See 7.6.5.)*

6.3.9 Fire Resistance Rating.

6.3.9.1 Interior stairs, elevators, and manlifts shall be enclosed in dusttight shafts that have a minimum fire resistance rating of 1 hour.

6.3.9.2 Doors that are the automatic-closing or self-closing type and have a fire resistance rating of 1 hour shall be provided at each landing.

6.3.9.3 Stairs, elevators, and manlifts that serve only open-deck floors, mezzanines, and platforms shall not be required to be enclosed.

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

6.4* Deflagration Venting.

6.4.1* If a room or building contains a dust explosion hazard as specified in 6.2.3.1 that is external to protected equipment, such areas shall be provided with deflagration venting to a safe outside location.

6.4.2* Vent Closures.

6.4.2.1 Vent closures shall be directed toward a restricted area.

6.4.2.2 The vent closure shall not be a missile hazard.

6.4.2.3 The fireball and the blast pressure that are created by the venting process shall not impinge on unrestricted personnel pathways.

6.5* Relief Valves. Relief valves shall not be vented to a dust hazard area, as specified by 6.2.3.1.

6.6 Electrical Equipment.

6.6.1 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*.

6.6.2* In local areas of a plant where a hazardous quantity of dust accumulates or is suspended in 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.

6.6.3 Hazardous (classified) areas that are identified in accordance with 6.6.2 shall be documented, and such documentation shall be permanently maintained on file for the life of the facility.

Chapter 7 Process Equipment

7.1* General. Methods of fire and explosion protection for specific equipment shall be in accordance with this section.

7.1.1* Risk Evaluation. A documented risk evaluation acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of protection to be provided.

7.1.2 Explosion Protection for Equipment.

7.1.2.1 The design of explosion protection for equipment shall incorporate one or more of the following methods of protection:

(1) Oxidant concentration reduction in accordance with NFPA 69, *Standard on Explosion Prevention Systems*
   (a) Where oxygen monitoring is used, it shall be installed in accordance with ISA 84.00.01, *Functional Safety: Application of Safety Instrumented Systems for the Process Industry Sector*.
   (b)*Where the chemical properties of the material being conveyed require a minimum concentration of oxygen to control pyrophoricity, that level of concentration shall be maintained.

(2)*Deflagration venting

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

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

(5)*Dilution with a noncombustible dust to render the mixture noncombustible *(See 7.1.2.2.)*

(6)*Deflagration venting through a listed dust retention and flame-arresting device

7.1.2.2 If the method in 7.1.2.1(5) is used, test data for specific dust and diluent combinations shall be provided and shall be acceptable to the authority having jurisdiction.

7.1.3 Fire Protection for Equipment. Equipment fire protection shall be designed in accordance with Chapter 10.

7.1.4* Isolation of Equipment.

7.1.4.1 Where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between pieces of equipment connected by ductwork.

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7.1.4.2 Isolation devices shall include, but shall not be limited to, the following:

(1)*Chokes
(2)*Rotary valves
(3)*Automatic fast-acting valve systems in accordance with NFPA 69, *Standard on Explosion Prevention Systems*
(4)*Flame front diverters in accordance with NFPA 69, *Standard on Explosion Prevention Systems*
(5)*Chemical isolation systems in accordance with NFPA 69, *Standard on Explosion Prevention Systems*

7.1.4.3 Isolation devices shall not be required when oxidant concentration has been reduced or when the dust has been rendered noncombustible in accordance with 7.1.2.1(1) or 7.1.2.1(5).

7.1.4.4* Isolation devices shall not be required if a documented risk evaluation that is acceptable to the authority having jurisdiction determines that deflagration propagation will not occur.

7.1.5* Deflagration Isolation.

7.1.5.1 Where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation from air–material separators upstream to the work areas.

7.1.5.2 Isolation devices shall include, but shall not be limited to, those listed in 7.1.4.2(1) through 7.1.4.2(5).

7.1.5.3 Isolation devices shall not be required if a documented risk evaluation that is acceptable to the authority having jurisdiction determines that deflagration propagation will not occur.

7.1.6 Fire Protection for Facility. Where a fire propagation hazard exists, the requirements of Chapter 10 shall apply.

7.2 Bulk Storage Enclosures.

7.2.1 General.

7.2.1.1 For the purposes of this section, bulk storage shall include items such as bins, tanks, hoppers, and silos.

7.2.1.2* The requirements of this section shall not apply to containers that are used for transportation of the material.

7.2.2 Construction. Bulk storage containers, whether located inside or outside of buildings, shall be constructed so as not to represent an increase in the fire load beyond the capabilities of the existing fire protection.

7.2.3 Explosion Hazards.

7.2.3.1 Where an explosion hazard exists, intertank or interbin venting shall not be permitted.

7.2.3.2 Fixed Bulk Storage Location.

7.2.3.2.1 Where an explosion hazard exists, fixed bulk storage containers shall be located outside of buildings.

7.2.3.2.2 Fixed bulk storage containers shall be permitted to be located inside of buildings where one of the following applies:

(1) Fixed bulk storage containers are protected in accordance with 7.1.2.1(1), 7.1.2.1(3), 7.1.2.1(4), 7.1.2.1(5), or 7.1.2.1(6).
(2)*Fixed bulk storage containers meet all of the following criteria:
  (a) They are equipped with deflagration vents that are vented through ducts to the outside.
  (b) The reduced venting efficiency due to the duct has been taken into account.
  (c) The ducts are designed to withstand the effects of the deflagration.
(3)*Fixed bulk storage containers are 8 ft^3 (0.2 m^3) or less.

7.2.3.3 Fixed Bulk Storage Protection.

7.2.3.3.1 Where an explosion hazard exists, fixed bulk storage containers shall be protected in accordance with 7.1.2.

7.2.3.3.2 For fixed bulk storage containers that are located outside of buildings, a risk evaluation shall be permitted to be conducted to determine the level of explosion protection to be provided.

7.2.3.3.3* The explosion protection requirements of 7.1.2 shall not be required provided that the volume of the fixed bulk storage container is less than 8 ft^3 (0.2 m^3).

7.2.3.3.4 The requirements of 7.2.3.3 shall not apply to storage and receiving containers that are used for transportation of the material.

7.2.4* Interior Surfaces. Interior surfaces shall be designed and constructed to facilitate cleaning and to minimize combustible dust accumulation.

7.2.5* Access Doors and Openings.

7.2.5.1 Access doors or openings shall be provided to allow inspection, cleaning, and maintenance.

7.2.5.2 Access doors or openings shall be designed to prevent dust leaks.

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

7.2.5.4 Access doors shall be bonded and grounded.

7.3 Material Transfer System.

7.3.1 General.

7.3.1.1* Where more than one material is to be handled by a system, compatibility tests shall be run.

7.3.1.2 Where incompatibility is found, provisions shall be made for cleaning the system prior to transporting a new material.

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

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

7.3.2 Pneumatic Conveying Systems.

7.3.2.1 The addition of branch lines shall not be made to an existing system without redesigning the entire system.

7.3.2.2 Branch lines shall not be disconnected and unused portions of the system shall not be blanked off without providing a means to maintain required and balanced airflow.

7.3.2.3 The rate of airflow at each hood or other pickup point shall be designed so as to convey and control the material.

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7.3.2.4* All ductwork shall be sized to provide the air volume and air velocity necessary to keep the duct interior clean and free of residual material.

7.3.2.5 The design of the pneumatic conveyance system shall be documented, including the following information:

(1) Data on the range of particulate size
(2) Concentration in conveyance air stream
(3) Potential for reaction between the transported particulate and the extinguishing media used to protect process equipment
(4) Conductivity of the particulate
(5) Other physical and chemical properties that affect the fire protection of the process

7.3.2.6 Pneumatic conveying systems that remove material from operations that generate flames, sparks, or hot material shall not be interconnected with pneumatic conveying systems that transport combustible particulate solids or hybrid mixtures.

7.3.3 Operations.

7.3.3.1 Sequence of Operation. Pneumatic conveying systems shall be designed with the operating logic, sequencing, and timing outlined in 7.3.3.2 and 7.3.3.3.

7.3.3.2* Startup. Pneumatic conveying systems shall be designed such that, on startup, the system achieves and maintains design air velocity prior to the admission of material to the system.

7.3.3.3 Shutdown. Pneumatic conveying systems shall be designed such that, on shutdown of the process, the system maintains design air velocity until material is purged from the system.

7.4 Specific Requirements for Systems that Convey Metal Particulates.

7.4.1 General. This section shall apply to facilities that operate pneumatic conveying systems for metal particulates.

7.4.1.1* Water Reactivity.

7.4.1.1.1 Unless otherwise determined, metal particulates shall be deemed water-reactive, and water-based extinguishing agents shall not be used.

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

7.4.1.1.3 The requirement of 7.4.1.1.1 shall not apply to the collection of iron dusts from shot blasting.

7.4.1.2 Systems that convey alloys that exhibit fire or explosion characteristics similar to those of the base metal shall be provided with the same protection as systems that convey the base metal.

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

7.5 Systems That Convey Hybrid Mixtures. The percentage of the lower flammable limit (LFL) of flammable vapors and the percentage of the minimum explosible concentration (MEC) of combustible dusts, when combined, shall not exceed 25 percent within the airstream, except for systems protected in accordance with 7.1.2.1(1) through 7.1.2.1(4).

7.6 Duct Systems.

7.6.1 Ducts that handle combustible particulate solids shall conform to the requirements of NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids,* except as amended by the requirements of this chapter.

7.6.2 Flexible hose and connections shall be permitted to be used for material pickup and isolation.

7.6.3 Bellows shall be permitted to be used for the free movement of weigh bins if the bellows are conductive and the equipment is bonded and grounded.

7.6.4* Changes in duct sizes shall be designed to prevent the accumulation of material by utilizing a tapered transformation piece with the included angle of the taper not more than 30 degrees.

7.6.5* When ducts pass through a physical barrier that is erected to segregate dust deflagration hazards, physical isolation protection shall be provided to prevent propagation of deflagrations between segregated spaces.

7.7 Sight Glasses.

7.7.1 Sight glasses shall be of a material that is impact and erosion resistant.

7.7.2 Sight glass assemblies shall have a pressure rating equal to or greater than that of the ductwork.

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

7.7.4 The mechanical strength of the sight glass–mounting mechanism shall be equal to the adjoining ductwork.

7.7.5 The inside diameter of a sight glass shall not cause a restriction of flow.

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

7.7.7 The electrical bonding across the length of the sight glass shall be continuous and have a resistance of no more than 1 ohm.

7.8 Pressure Protection Systems.

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

7.8.2* Pressure Relief Devices.

7.8.2.1 Pressure relief devices for relief of pneumatic overpressure shall be installed on positive-pressure systems.

7.8.2.2 The requirement of 7.8.2.1 shall not apply to systems that are designed for a gauge pressure of less than 15 psi (103 kPa) and are provided with safety interlocks designed to prevent overpressure in accordance with ISA 84.00.01, *Functional Safety: Application of Safety Instrumented Systems for the Process Industry Sector.*

7.8.2.3 The requirement of 7.8.2.1 shall not apply to systems that are designed for a gauge pressure of less than 15 psi (103 kPa) and are capable of containing the maximum pressure attainable.

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7.8.3 Airflow Control Valves.

7.8.3.1 Airflow control valves that are installed in pneumatic systems shall be of both airtight and dusttight construction.

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

7.8.3.3 The position of airflow control valves shall be visually indicated.

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

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

7.9 Material Feeding Devices.

7.9.1 Mechanical Feeding Devices.

7.9.1.1 Mechanical feeding devices shall be equipped with a shear pin or overload detection device and alarm.

7.9.1.2 The alarm shall sound at the operator control station.

7.9.2 Drives.

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

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

7.10* Bucket Elevators.

7.10.1* Deflagration Venting.

7.10.1.1 Where an explosion hazard exists, bucket elevators shall be provided with deflagration venting.

7.10.1.2 When bucket elevators are located inside the building, deflagration vents shall be ducted to the outside.

7.10.1.3 As an alternative to deflagration venting, bucket elevators shall be permitted to be protected in accordance with 7.1.2.1(1), 7.1.2.1(3), 7.1.2.1(4), 7.1.2.1(5), 7.1.2.1(6), or 7.1.4.2(5).

7.10.2 Elevator casings, head and boot sections, and connecting ducts shall be dusttight and shall be constructed of noncombustible materials.

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

7.10.4 Power Cutoff.

7.10.4.1* Belt-driven bucket elevators shall be provided with a detector that cuts off the power to the drive motor if the motor speed drops below 80 percent of normal operating speed.

7.10.4.2 Feed to the elevator leg shall be stopped or diverted when the power to the motor is stopped.

7.10.5 Belts.

7.10.5.1 Belt-driven bucket elevators shall have a nonslip material (lagging) installed on the head pulley to minimize slippage.

7.10.5.2* Belts and lagging shall be fire and oil resistant.

7.10.6 No bearings shall be located in the bucket elevator casing.

7.10.7* Head and boot sections shall be provided with openings to allow for cleanout, inspection, and alignment of the pulley and belt.

7.10.8 Drive.

7.10.8.1* The bucket elevator shall be driven by a motor and drive train that is capable of handling the full-rated capacity of the elevator without overloading.

7.10.8.2 The drive shall be capable of starting the unchoked elevator under full (100 percent) load.

7.10.9 Monitors.

7.10.9.1 Elevators shall have monitors at head and tail pulleys that indicate high bearing temperature, vibration detection, head pulley alignment, and belt alignment.

7.10.9.2 Abnormal conditions shall actuate an alarm requiring corrective action.

7.10.9.3 The alarm shall sound at the operator control station.

7.10.9.4 The requirement of 7.10.9.1 shall not apply to elevators that have belt speeds below 500 ft/min (150 m/min) or capacities less than 3750 ft^3/hr (106 m^3/hr).

7.10.10 Emergency Controls.

7.10.10.1 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.

7.10.10.2 The audible alarm specified in 7.10.10.1 shall sound at the operator control station.

7.11* Enclosed Conveyors.

7.11.1 Housing and Coverings.

7.11.1.1 Where an explosion hazard exists within enclosed conveyors, they shall be protected in accordance with 7.1.2.

7.11.1.2 Housings for enclosed conveyors (e.g., screw conveyors and drag conveyors) shall be of metal construction and shall be designed so as to prevent escape of combustible dusts.

7.11.1.3 Coverings on cleanout, inspection, and other openings shall be fastened to prevent the escape of combustible dusts.

7.11.2 Power Shutoff.

7.11.2.1* 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.

7.11.2.2 The alarm shall sound at the operator control station, and feed to the conveyor shall be stopped or diverted.

7.12 Air-Moving Devices (Fans and Blowers).

7.12.1 Air-moving devices shall conform to the requirements of NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, except as amended by the requirements of this chapter.

7.12.2 Combustible Particulate Solids.

7.12.2.1 Where an explosion hazard exists, systems shall be designed in such a manner that combustible particulate solids do not pass through an air-moving device.

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7.12.2.2* The requirement of 7.12.2.1 shall not apply to systems designed to operate at a combustible particulate solids concentration or hybrid mixture concentration of less than 0.0003 oz/ft^3 (0.3 g/m^3).

7.12.2.3* The requirement of 7.12.2.1 shall not apply to systems meeting both of the following criteria:

(1) Systems operating at a combustible particulate solids concentration or hybrid mixture concentration equal to or greater than 0.0003 oz/ft^3 (0.3 g/m^3)
(2) Systems protected by an approved explosion prevention or isolation system to prevent the propagation of the flame front from the fan to other equipment in accordance with 7.1.2.1(1), 7.1.2.1(4), 7.1.2.1(5), 7.1.4.2(3), 7.1.4.2(4), or 7.1.4.2(5).

7.12.3 Where a fire hazard exists and where combustible particulate solids pass through an air-moving device, provisions shall be made to prevent ignited material from entering processes downstream, in accordance with Chapter 10.

7.13 Air–Material Separators (Air Separation Devices).

7.13.1 General.

7.13.1.1 Location.

7.13.1.1.1 Where an explosion hazard exists, air–material separators shall be located outside of buildings.

7.13.1.1.2* The requirement of 7.13.1.1.1 shall not apply to the following:

(1) Air–material separators that are protected in accordance with 7.1.2.1(1), 7.1.2.1(3), 7.1.2.1(4), 7.1.2.1(5), or 7.1.2.1(6)
(2) Air–material separators that meet all of the following criteria:
    (a) They are equipped with deflagration vents that are vented through ducts to the outside.
    (b) The reduced venting efficiency due to the duct has been taken into account.
    (c) The ducts are designed to withstand the effects of the deflagration.
(3) Air–material separators that have a volume of less than 8 ft^3 (0.2 m^3)

7.13.1.2 Where both an explosion hazard and a fire hazard exist in an air–material separator, provisions for protection for each type of hazard shall be provided.

7.13.1.3 Protection.

7.13.1.3.1 Air–material separators shall be protected in accordance with 7.1.2.

7.13.1.3.2 For air–material separators that are located outside of buildings, a risk evaluation shall be permitted to be conducted to determine the level of explosion protection to be provided.

7.13.1.4 Manifolding of Dust Collection Ducts.

7.13.1.4.1 Manifolding of dust collection ducts to air–material separators shall not be permitted.

7.13.1.4.2 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.

7.13.1.4.3 Dust collection ducts from nonassociated pieces of equipment shall be permitted to be manifolded provided that each duct is equipped with an isolation device prior to manifolding in accordance with 7.1.4.

7.13.1.4.4 Dust collection ducts for centralized vacuum cleaning systems shall be permitted to be manifolded.

7.13.1.5* Isolation devices shall be provided for air–material separators in accordance with 7.1.4.

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

7.13.1.7 Exhaust Air.

7.13.1.7.1 Exhaust air from the final air–material separator shall be discharged outside to a restricted area and away from air intakes.

7.13.1.7.2 Air from air–material separators shall be permitted to be recirculated directly back to the pneumatic conveying system.

7.13.1.7.3 Air from air–material separators shall be permitted to be returned to the building when in compliance with the requirements of 6.1.3.

7.13.1.8 Where more than one material is to be handled by a system and is known to be incompatible, provisions shall be made for cleaning the system prior to the handling of a new material.

7.13.2 Construction.

7.13.2.1 Noncombustible Material.

7.13.2.1.1 Air–material separators shall be constructed of noncombustible materials.

7.13.2.1.2 Filter media shall be permitted to be constructed of combustible material.

7.13.2.2 Maximum Material Flow.

7.13.2.2.1 Air–material separators shall be constructed to minimize internal ledges or other points of dust accumulation.

7.13.2.2.2 Hopper bottoms shall be sloped, and the discharge conveying system shall be designed to handle the maximum material flow attainable from the system.

7.13.2.3 Access Doors.

7.13.2.3.1 Access doors or openings shall be provided to permit inspection, cleaning, and maintenance.

7.13.2.3.2 Access doors or openings shall be designed to prevent dust leaks.

7.13.2.3.3 Access doors shall be permitted to be used as deflagration vents if they are specifically designed for both purposes.

7.13.2.3.4 Access doors shall be bonded and grounded.

7.13.2.3.5* Access doors shall be designed to withstand the vented explosion pressure (P_{red}).

7.14* Abort Gates/Abort Dampers.

7.14.1 Construction.

7.14.1.1 Abort gates and abort dampers shall be constructed of noncombustible materials.

7.14.1.2 Abort gates shall be actuated by spark detection in the duct or pipe upstream of the device.

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7.14.1.3 The detection system and abort gate shall respond to prevent sparks, glowing embers, or burning materials from passing beyond the abort gate.

7.14.2 Operation.

7.14.2.1 The abort gate or abort damper shall be installed so that it diverts airflow to a restricted area to safely discharge combustion gases, flames, burning solids, or process gases or fumes.

7.14.2.2 Manual Reset.

7.14.2.2.1 The abort gate or abort damper shall be provided with a manual reset such that, subsequent to operation, it can be returned only to the normal operating position at the damper (gate).

7.14.2.2.2 Automatic or remote reset provisions shall not be permitted.

7.15* Size Reduction.

7.15.1 Before material is processed by size reduction equipment, foreign materials shall be excluded or removed as required by 9.1.1.

7.15.2 Where an explosion hazard exists, protection shall be provided as specified in 7.1.2.

7.15.3 Where a fire hazard exists, protection shall be provided in accordance with Chapter 10.

7.16* Particle Size Separation.

7.16.1 Particle separation devices shall be in dusttight enclosures.

7.16.2 Connection ducts shall be in conformance with Section 7.6.

7.16.3* Explosion Protection.

7.16.3.1 Where an explosion hazard exists, protection shall be provided as specified in 7.1.2.

7.16.3.2* Screens and sieves shall not be required to have explosion protection.

7.16.4 Where a fire hazard exists, protection shall be in accordance with Chapter 10.

7.17 Mixers and Blenders.

7.17.1 Mixers and blenders shall be dusttight.

7.17.2 Foreign materials shall be excluded or removed as required by 9.1.1.

7.17.3 Where an explosion hazard exists, protection shall be provided as specified in 7.1.2.

7.17.4 Where a fire hazard exists, protection shall be in accordance with Chapter 10.

7.17.5 Mixers and blenders shall be made of metal, other noncombustible material, or a material that does not represent an increased fire load beyond the capabilities of the existing fire protection.

7.18* Dryers.

7.18.1 Heating systems shall be in accordance with Section 9.6.

7.18.2 Drying Media.

7.18.2.1 Drying media that come into contact with material being processed shall not be recycled to rooms or buildings.

7.18.2.2 Drying media shall be permitted to be recycled to the drying process provided the following conditions are met:

(1) The media passes through a filter, dust separator, or equivalent means of dust removal.
(2) The vapor flammability of the drying media in the dryer is controlled by either oxidant concentration reduction or combustible concentration reduction in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

7.18.3 Dryers shall be constructed of noncombustible materials.

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

7.18.5 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.

7.18.6 Where an explosion hazard exists, protection shall be provided as specified in 7.1.2.

7.18.7 Where a fire hazard exists, protection shall be in accordance with Chapter 10.

7.18.8 Heated dryers shall comply with NFPA 86, *Standard for Ovens and Furnaces*.

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

7.18.10 Heated dryers and their auxiliary equipment shall be equipped with separate excess-temperature-limit controls, independent of the operating controls, that are arranged to supervise the following:

(1) Heated air supply to the drying chamber
(2) Airstream at the discharge of the drying chamber

Chapter 8 Fugitive Dust Control and Housekeeping

8.1 Fugitive Dust Control.

8.1.1 Continuous suction to minimize the escape of dust shall be provided for processes where combustible dust is liberated in normal operation.

8.1.2 The dust shall be conveyed to dust collectors.

8.2 Housekeeping. The requirements of 8.2.1 through 8.2.3 shall be applied retroactively.

8.2.1* General.

8.2.1.1 Equipment shall be maintained and operated in a manner that minimizes the escape of dust.

8.2.1.2 Regular cleaning frequencies shall be established for walls, floors, and horizontal surfaces, such as equipment, ducts, pipes, hoods, ledges, beams, and above suspended ceilings and other concealed surfaces, to minimize dust accumulations within operating areas of the facility.

8.2.2* Dust Clouds.

8.2.2.1 Surfaces shall be cleaned in a manner that minimizes the generation of dust clouds.

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8.2.2.2 Vigorous sweeping or blowing down with steam or compressed air produces dust clouds and shall be permitted only where the following requirements are met:

(1) Area and equipment shall be vacuumed prior to blowdown.
(2) Electrical equipment not suitable for Class II locations and other sources of ignition shall be shut down or removed from the area.
(3) Only low-pressure steam or compressed air, not exceeding a gauge pressure of 15 psi (103 kPa), shall be used.
(4) No hot surfaces or flames capable of igniting a dust cloud or layer shall exist in the area.

8.2.3 Vacuum Cleaners.

8.2.3.1 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 7.13.

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

Chapter 9 Ignition Sources

9.1 Heat from Mechanical Sparks and Friction.

9.1.1 Foreign Materials.

9.1.1.1 Means shall be provided to prevent foreign material from entering the system when such foreign material presents an ignition hazard.

9.1.1.2 Floor sweepings shall not be returned to any machine.

9.1.1.3* Foreign materials, such as tramp metal, that are capable of igniting combustible material being processed shall be removed from the process stream by one of the following methods:

(1) Permanent magnetic separators or electromagnetic separators that indicate loss of power to the separators
(2) Pneumatic separators
(3) Grates or other separation devices

9.1.2* Inherently Ignitible Process Streams.

9.1.2.1 Where the process is configured such that the pneumatic conveying system conveys materials that can act as an ignition source, means shall be provided to minimize the hazard.

9.1.2.2 The means used to minimize the ignition source hazard specified in 9.1.2.1 shall be permitted to include protection measures identified in 7.1.1 and Section 10.1, as appropriate.

9.1.3* Belt Drives. Belt drives shall be designed to stall without the belt's slipping, or a safety device shall be provided to shut down the equipment if slippage occurs.

9.1.4* Bearings.

9.1.4.1 Roller or ball bearings shall be used on all processing and transfer equipment.

9.1.4.2 Bushings shall be permitted to be used when a documented engineering evaluation shows that mechanical loads and speeds preclude ignition due to frictional heating.

9.1.4.3 Lubrication shall be performed in accordance with the manufacturer's recommendations.

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

9.2 Electrical Equipment. All electrical equipment and installations shall comply with the requirements of Section 6.6.

9.3* Static Electricity. The requirements of 9.3.1 and 9.3.2 shall be applied retroactively.

9.3.1* Conductive Components.

9.3.1.1 All system components shall be conductive.

9.3.1.2 Where the use of conductive components is not practical, nonconductive equipment shall be permitted where one of the following criteria is met:

(1) A documented engineering analysis that is acceptable to the authority having jurisdiction has determined that no electrostatic ignition potential exists.
(2) Materials being conveyed are not compatible with metal ductwork, and other means of explosion protection are provided in accordance with 7.1.2.1(1), 7.1.2.1(3), 7.1.2.1(4), or 7.1.2.1(5).

9.3.1.3 Bonding and grounding with a resistance of less than 1.0×10^6 ohms to ground shall be provided for conductive components.

9.3.2 Where belt drives are used, the belts shall be electrically conductive and have a resistance of less than 1.0×10^6 ohms to ground.

9.3.3 Intermediate Bulk Containers (IBCs).

9.3.3.1* Dispensing material from intermediate bulk containers into combustible atmospheres shall be performed only under the following conditions:

(1) A conductive (i.e., metallic) rigid intermediate bulk container (RIBC) shall be permitted to be used for dispensing into any flammable vapor, gas, dust, or hybrid atmospheres provided the RIBC is electrically grounded.
(2)* A Type B flexible intermediate bulk container (FIBC) shall be permitted to be used for dispensing into dust atmospheres where the minimum ignition energy (MIE) is greater than 3 mJ, but no flammable vapor or gas is present.
(3)* A Type C FIBC shall be permitted to be used for dispensing into any flammable vapor, gas, dust, or hybrid atmosphere for which the FIBC has been tested and found suitable, provided the FIBC is electrically grounded with a resistance less than 1 megohm to ground.
(4)* A Type D FIBC shall be permitted to be used for dispensing into flammable vapor, gas, dust, or hybrid atmospheres for which the FIBC has been tested and found suitable.
(5)* A Type A FIBC or insulating RIBCs shall not be permitted to be used for combustible powder applications, processes, or operations unless a documented risk evaluation assessing the electrostatic hazards is acceptable to the authority having jurisdiction.

9.3.3.2* FIBCs that are listed or tested by a recognized testing organization and are shown not to ignite flammable atmospheres during transfer shall be permitted to be used.

9.3.3.3 Documentation of test results shall be made available to the authority having jurisdiction.

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9.3.4 Particulate solids shall not be manually dumped directly into vessels containing flammable atmospheres (gases at a flammable concentration with an oxidant) or where displacement could cause a flammable atmosphere external to the vessel.

9.3.5 Manual additions of solids through an open port or a manway into a vessel containing flammable vapors shall be permitted to be done in 50 lb (25 kg) batches or smaller.

9.4 Cartridge-Actuated Tools. The requirements of 9.4.1 through 9.4.3 shall be applied retroactively.

9.4.1 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 cleaned and inspected to ensure the removal of all accumulations of combustible material.

9.4.2 Accepted lockout/tagout procedures shall be followed for the shutdown of machinery.

9.4.3 The use of cartridge-actuated tools shall be in accordance with 9.5.2.

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

9.5 Open Flames and Sparks. The requirements of 9.5.1 through 9.5.3 shall be applied retroactively.

9.5.1 Cutting and welding shall comply with the applicable requirements of NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

9.5.2 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 During Welding, Cutting, and Other Hot Work*.

9.5.3 Smoking shall be permitted only in designated areas.

9.6 Process and Comfort Heating Systems.

9.6.1* In areas processing combustible dust, process and comfort heating shall be provided by indirect means.

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

9.6.3 Air for combustion shall be taken from a clean outside source.

9.6.4 Comfort air systems for processing areas containing combustible dust shall not be recirculated.

9.6.5 Recirculating systems shall be permitted to be used provided that all of the following criteria are met:

(1) Only fresh makeup air is heated.
(2) The return air is filtered to prevent accumulations of dust in the recirculating system.
(3) The exhaust flow is balanced with fresh air intake.

9.6.6 Comfort air shall not be permitted to flow from hazardous to nonhazardous areas.

9.7* Hot Surfaces. The temperature of external surfaces, such as compressors; steam, water, or process piping; ducts; and process equipment, in an area containing a combustible dust shall be maintained below 80 percent of the minimum ignition temperature of the dust layer as determined by recognized test methods acceptable to the authority having jurisdiction or 329°F (165°C), whichever is lower.

9.8 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 6.6, shall be used in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations*.

Chapter 10 Fire Protection

10.1 General. Fire protection systems, where installed, shall be specifically designed to address building protection, process equipment, and the chemical and physical properties of the materials being processed.

10.2 System Requirements. Fire protection systems required by this standard shall comply with 10.2.1 and 10.2.9.

10.2.1* Fire-extinguishing agents shall be compatible with the conveyed materials.

10.2.2 Where fire detection systems are incorporated into pneumatic conveying systems, an analysis shall be conducted to identify safe interlocking requirements for air-moving devices and process operations.

10.2.3 Detection Systems.

10.2.3.1 Where fire detection systems are incorporated into the pneumatic conveying system, the fire detection systems shall be interlocked to shut down any active device feeding materials to the pneumatic conveying system on actuation of the detection system.

10.2.3.2 Where spark or infrared detection and extinguishing systems are provided, the process shall be permitted to continue operating on activation of the detection system.

10.2.3.3 Where a spark or infrared detection system actuates a diverter valve that sends potentially burning material to a safe location, the process shall be permitted to continue operating on activation of the detection system.

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

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

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

10.2.7 System Releasing Devices.

10.2.7.1 All fire-extinguishing system releasing devices, solenoids, or actuators shall be connected to the fire detection control panel via Style Z circuits as described in *NFPA 72, National Fire Alarm Code*.

10.2.7.2 The supervision shall include the continuity of the extinguishing system releasing device, whether that device

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is a solenoid coil, a detonator (explosive device) filament, or other such device.

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

10.2.9 Abort Gates and Abort Dampers.

10.2.9.1 All fire protection abort gates or abort dampers shall be connected to the fire detection control panel via Style Z circuits as described in *NFPA 72, National Fire Alarm Code*.

10.2.9.2 The supervision shall include the continuity of the abort gate or abort damper releasing device, whether that device is a solenoid coil, a detonator (explosive device) filament, or other such device.

10.3 Fire Extinguishers.

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

10.3.2* Personnel shall be trained to use portable fire extinguishers in a manner that minimizes the generation of dust clouds during discharge.

10.4 Hose, Standpipes, and Hydrants.

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

10.4.2 Nozzles.

10.4.2.1 Portable spray hose nozzles that are listed or approved for use on Class C fires shall be provided in areas that contain dust, to limit the potential for generating unnecessary airborne dust during fire-fighting operations.

10.4.2.2 Straight-stream nozzles shall not be used on fires in areas where dust clouds can be generated.

10.4.3 Private outside protection, including outside hydrants and hoses, where provided, shall comply with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

10.5* Automatic Sprinklers.

10.5.1* Where a process that handles combustible particulate solids uses flammable or combustible liquids, a documented risk evaluation that is 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.

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

10.5.3 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.

10.6 Spark/Ember Detection and Extinguishing Systems. Spark/ember detection and extinguishing systems shall be designed, installed, and maintained in accordance with NFPA 69, *Standard on Explosion Prevention Systems*, and *NFPA 72, National Fire Alarm Code*.

10.7 Special Fire Protection Systems.

10.7.1 Automatic extinguishing systems or special hazard extinguishing systems, where provided, shall be designed, installed, and maintained in accordance with the following standards, as applicable:

(1) NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*
(2) NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*
(3) NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*
(4) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*
(5) NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*
(6) NFPA 17, *Standard for Dry Chemical Extinguishing Systems*
(7) NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*
(8) NFPA 750, *Standard on Water Mist Fire Protection Systems*
(9) NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*

10.7.2 The extinguishing systems shall be designed and used in a manner that minimizes the generation of dust clouds during their discharge.

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

Chapter 11 Training and Procedures

11.1 Employee Training. The requirements of Sections 11.2 and 11.3 shall be applied retroactively.

11.2 Plan.

11.2.1 Operating and maintenance procedures and emergency plans shall be developed.

11.2.2 The plans and procedures shall be reviewed annually and as required by process changes.

11.3 Initial and Refresher Training.

11.3.1 Initial and refresher training shall be provided to employees who are involved in operating, maintaining, and supervising facilities that handle combustible particulate solids.

11.3.2 Initial and refresher training shall ensure that all employees are knowledgeable about the following:

(1) Hazards of their workplace
(2) General orientation, including plant safety rules
(3) Process description
(4) Equipment operation, safe startup and shutdown, and response to upset conditions
(5) The necessity for proper functioning of related fire and explosion protection systems
(6) Equipment maintenance requirements and practices
(7) Housekeeping requirements
(8)*Emergency response plans

11.4 Certification. The employer shall certify annually that the training and review required by Sections 11.2 and 11.3 have been completed.

Chapter 12 Inspection and Maintenance

12.1 General Requirements. The requirements of 12.1.1 through 12.1.3 shall be applied retroactively.

12.1.1 An inspection, testing, and maintenance program shall be developed and implemented to ensure that the fire

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and explosion protection systems and related process controls and equipment perform as designed.

12.1.2 The inspection, testing, and maintenance program shall include the following:

(1) Fire and explosion protection and prevention equipment in accordance with the applicable NFPA standards
(2) Dust control equipment
(3) Housekeeping
(4) Potential ignition sources
(5)*Electrical, process, and mechanical equipment, including process interlocks
(6) Process changes
(7) Lubrication of bearings

12.1.3 Records shall be kept of maintenance and repairs performed.

12.2 Specific Requirements.

12.2.1 Maintenance of Material Feeding Devices.

12.2.1.1 Bearings shall be lubricated and checked for excessive wear on a periodic basis.

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

12.2.2 Maintenance of Air-Moving Devices.

12.2.2.1 Fans and blowers shall be checked periodically for excessive heat and vibration.

12.2.2.2 Maintenance, other than the lubrication of external bearings, shall not be performed on fans or blowers while the unit is operating.

12.2.2.3 Bearings shall be lubricated and checked periodically for excessive wear.

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

12.2.2.5* The surfaces of fan housings and other interior components shall be maintained free of rust.

12.2.2.6 Aluminum paint shall not be used on interior steel surfaces.

12.2.3 Maintenance of Air–Material Separators.

12.2.3.1 Means to Dislodge.

12.2.3.1.1 Air–material separation devices that are equipped with a means to dislodge particulates from the surface of filter media shall be inspected periodically as recommended in the manufacturers' instructions for signs of wear, friction, or clogging.

12.2.3.1.2 These devices shall be adjusted and lubricated as recommended in the manufacturers' instructions.

12.2.3.2 Air–material separators that recycle air (i.e., cyclones and filter media dust collectors) shall be maintained to comply with 6.1.3.

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

12.2.4 Maintenance of Abort Gates and Abort Dampers. Abort gates and abort dampers shall be adjusted and lubricated as recommended in the manufacturers' instructions.

12.2.5 Maintenance of Fire and Explosion Protection Systems.

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

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

12.2.5.3* All vents for the relief of pressure caused by deflagrations shall be maintained.

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

Annex A Explanatory Material

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

A.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 the following:

(1) Agricultural, chemical, and food commodities, fibers, and textile materials
(2) Forest and furniture products industries
(3) Metals processing
(4) Paper products
(5) Pharmaceuticals
(6) Resource recovery operations (tires, municipal solid waste, metal, paper, or plastic recycling operations)
(7) Wood, metal, or plastic fabricators

A.3.2.1 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.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, 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 repre-

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sentative 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.3.2.4 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.3.3.2 Air–Material Separator (AMS). Examples include cyclones, bag filter houses, and electrostatic precipitators.

A.3.3.3 Air-Moving Device (AMD). An air-moving device is a fan, centrifugal fan, or mixed flow fan. These devices have previously been called blowers or exhausters.

A.3.3.4 Combustible Dust. Dusts traditionally have been defined as a material 420 µm or smaller (capable of passing through a U.S. No. 40 standard sieve). Combustible particulates with an effective diameter of less than 420 µm should be deemed to fulfill the criterion of the definition. However, flat platelet-shaped particles, flakes, or particles of fibers with lengths that are large compared to their diameter usually do not pass through a 420 µm sieve yet still pose a deflagration hazard. Furthermore, many particulates accumulate electrostatic charge in handling, causing them to attract each other, forming agglomerates. Often agglomerates behave as if they were larger particles, yet when they are dispersed they present a significant hazard. Consequently, it can be inferred that any particle that has a surface area to volume ratio greater than that of a 420 µm diameter sphere should also be deemed a combustible dust.

Any time a combustible dust is processed or handled, a potential for deflagration exists. The degree of deflagration hazard varies, depending on the type of combustible dust and the processing methods used.

A dust explosion has the following four requirements:

(1) Combustible dust
(2) Dust dispersion in air or other oxidant at or exceeding the minimum explosible concentration (MEC)
(3) Ignition source such as an electrostatic discharge, an electric current arc, a glowing ember, a hot surface, welding slag, frictional heat, or a flame
(4) 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:

(1) Minimum explosible concentration (MEC)
(2) Minimum ignition energy (MIE)
(3) Particle size distribution
(4) Moisture content as received and as tested
(5) Maximum explosion pressure at optimum concentration
(6) Maximum rate of pressure rise at optimum concentration
(7) K_{St} (normalized rate of pressure rise) as defined in ASTM E 1226, *Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts*
(8) Layer ignition temperature
(9) Dust cloud ignition temperature
(10) Limiting oxidant concentration (LOC) to prevent ignition
(11) Electrical volume resistivity
(12) Charge relaxation time
(13) Chargeability

A.3.3.5 Combustible Particulate Solid. Combustible particulate solids include dusts, fibers, fines, chips, chunks, flakes, or mixtures of these. The term *combustible particulate solid* addresses the attrition of 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 could 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.3.3.7 Deflagration. The primary concern of this document is a deflagration that produces a propagating flame front or pressure increase that can cause personnel injuries or the rupture of process equipment or buildings. Usually these deflagrations are produced when the fuel is suspended in the oxidizing medium.

A.3.3.13 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, adds 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 MEC and the vapor is below the LFL. Furthermore, dusts determined to be nonignitible by weak ignition sources can sometimes be ignited when part of a hybrid mixture.

Examples of hybrid mixtures are a mixture of methane, coal dust, and air or a mixture of gasoline vapor and gasoline droplets in air.

A.3.3.14.2 Rigid Intermediate Bulk Container (RIBC). These are often called composite IBCs, which is the term used by U.S. Department of Transportation (DOT). The term *rigid nonmetallic intermediate bulk container* also denotes an all-plastic single-wall IBC that might or might not have a separate plastic base and for which the containment vessel also serves as the support structure.

A.3.3.15 Lower Flammable Limit (LFL). LFL is also known as minimum explosible concentration (MEC).

A.3.3.16 Minimum Explosible Concentration (MEC). Minimum explosible concentration is defined by the test procedure in ASTM E 1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*. MEC is equivalent to the term *lower flammable limit* for flammable gases. Because 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 on many factors, including particulate size distribution, chemistry, moisture content, and shape. Consequently, designers and operators of processes that handle combustible particulate solids should consider those factors when applying existing MEC data. Often, the necessary MEC data can be obtained only by testing.

A.3.3.17 Noncombustible Material. Materials that are reported as having passed ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, should be considered noncombustible materials. For the purposes of this standard, noncombustible construction and limited-combustible construction are both considered to be noncombustible.

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A.3.3.19 Pneumatic Conveying System. Pneumatic conveying systems include dust collection systems.

A.3.3.19.1 Negative-Pressure Pneumatic Conveying System. These systems consist of a sequence of an air intake, a material feeder, an air–material separator, an air-moving device, and interconnecting ducts.

A.3.3.19.2 Positive-Pressure Pneumatic Conveying System. Such systems consist of a sequence of an air-moving device, a feeder for introducing materials into the system, an air–material separator, and interconnecting ducts.

A.3.3.27 Water-Compatible. These materials include many of the cellulosics such as wood waste, paper dust, textile fibers, bulk agricultural products, municipal solid waste (MSW), refuse-derived fuel (RDF), and other organic materials, including coal and some plastic resins. Water spray extinguishment can be used for these materials when they are handled in systems in which the process equipment is also water-compatible.

A.3.3.28 Water-Incompatible. Water-incompatible materials are typified by those that dissolve in water or form mixtures with water that are no longer processable, for example, sugar. Although water is an effective extinguishing agent for sugar fires, the sugar dissolves in the water, resulting in a syrup that can no longer be processed pneumatically. A similar situation exists with flour; when mixed with water, it becomes dough. These materials are candidates for extinguishing systems that use media other than water until the damage potential of the fire approaches the replacement cost of the process equipment. Then water is used to protect the structure.

A.3.3.29 Water-Reactive. Water-reactive materials represent a very special fire protection problem. The application of water from fixed water-based extinguishing systems or by the fire service without awareness of the presence of these materials could seriously exacerbate the threat to human life or property. For example, many chemicals form strong acids or bases when mixed with water, thus introducing a chemical burn hazard. Additionally, most metals in the powdered state can burn with sufficient heat to chemically reduce water-yielding hydrogen, which can then support a deflagration.

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

A.4.1.2 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.4.2.1 One method by which this requirement can be satisfied is with a process hazard analysis conducted in accordance with the methods outlined by the AIChE Center for Chemical Process Safety in *Guidelines for Hazard Evaluation Procedures.*

A.4.4 The design of the pneumatic conveying system should be coordinated with the architectural and structural designs. The plans and specifications should include a list of all equipment, specifying the manufacturer and type number, and the information as shown in A.4.4(1) through A.4.4(8). Plans should be drawn to an indicated scale and show all essential details as to location, construction, ventilation ductwork, volume of outside air at standard temperature and pressure that is introduced for safety ventilation, and control wiring diagrams.

(1) Name of owner and occupant
(2) Location, including street address
(3) Point of compass
(4) Ceiling construction
(5) Full height cross section
(6) Location of fire walls
(7) Location of partitions
(8) Materials of construction

A.4.5.3 Other stakeholders could also have mission continuity goals that will necessitate more stringent objectives as well as more specific and demanding performance criteria. The protection of property beyond maintaining structural integrity long enough to escape is actually a mission continuity objective. The mission continuity objective encompasses the survival of both real property, such as the building, and the production equipment and inventory beyond the extinguishment of the fire. Traditionally, property protection objectives have addressed the impact of the fire on structural elements of a building as well as the equipment and contents inside a building. Mission continuity is concerned with the ability of a structure to perform its intended functions and with how that affects the structure's tenants. It often addresses post-fire smoke contamination, cleanup, replacement of damaged equipment or raw materials, and so forth.

A.4.5.4.1 Adjacent compartments are those sharing a common enclosure surface (wall, ceiling, floor) with the compartment of fire or explosion origin. The intent is to prevent the collapse of the structure during the fire or explosion.

A.4.6 Usually a facility or process system is designed using the prescriptive criteria until a prescribed solution is found to be unfeasible or impracticable. Then the designer can use the performance-based option to develop a design, addressing the full range of fire and explosion scenarios and the impact on other prescribed design features. Consequently, facilities are usually designed not by using performance-based design methods for all facets of the facility but rather by using a mixture of both design approaches as needed.

A.5.1.3 Chapter 5 of NFPA *101*, *Life Safety Code*, provides a more complete description of the performance-based design process and requirements. In addition, the *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* outlines a process for developing, evaluating, and documenting performance-based designs.

A.5.1.4 Relevant aspects that could require a re-evaluation include, but are not limited to, changes to the following:

(1) Information about the hazardous characteristics of the materials
(2) Information about the performance capabilities of protective systems
(3) Heretofore unrecognized hazards

Intentional changes to process materials, technology, equipment, procedures, and facilities are controlled by Section 4.3.

A.5.2.5(3) Deflagration vent operation does not constitute rupture of the equipment.

A.5.3 The process hazard analysis conducted according to the requirement in Section 4.2 might be useful in identifying the scenarios for Section 5.3.

The fire and explosion scenarios defined in Section 5.3 assume the presence of an ignition source, even those scenarios limited by administrative controls (such as a hot work

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permit program). It is the responsibility of the design professional to document any scenario that has been excluded on the basis of the absence of an ignition source.

A.5.4.1 The *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* outlines a process for evaluating whether trial designs meet the performance criteria.

A.6.1.1 The design of the pneumatic conveying system should be coordinated with the architectural and structural designs. The plans and specifications should include a list of all equipment, specifying the manufacturer and type number, and the following information:

(1) Name of owner and occupant
(2) Location, including street address
(3) Point of compass
(4) Ceiling construction
(5) Full height cross section
(6) Location of fire walls
(7) Location of partitions
(8) Materials of construction

Plans should be drawn to an indicated scale and show all essential details as to location, construction, ventilation ductwork, volume of outside air at standard temperature and pressure that is introduced for safety ventilation, and control wiring diagrams.

A.6.1.3.2 OSHA has established limits on oxygen concentration in the workplace. Permissible limits range from no lower than 19.5 percent by volume to no higher than 23.5 percent by volume in air. See Title 29, *Code of Federal Regulations*, Part 1910.146.

A.6.1.5 Except for inerted systems, it is preferable to design systems that handle combustible particulate solids to operate under negative pressure.

A.6.2.3.1 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. Such a 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. *(See Annex D.)*

A.6.3.3 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 and 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.6.3.10 The use of loadbearing walls should be avoided to prevent structural collapse should an explosion occur.

A.6.4 The design of deflagration venting should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations*.

A.6.4.1 The need for building deflagration venting is a function of equipment design, particle size, deflagration characteristics of the dust, and housekeeping requirements. As a rule, deflagration venting is recommended unless there can be reasonable assurance 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 is the preferred method of protection. Damage-limiting construction involves a room or building that is 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 to 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 remain open to prevent failure from the vacuum following the pressure wave.

A.6.4.2 For further information on restraining vent closures and fireball impingement areas, see NFPA 68, *Guide for Venting of Deflagrations*.

A.6.5 High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust.

A.6.6.2 Refer to NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*. See Table A.6.6.2.

A.7.1 The following items describe areas of concern during the design and installation of process equipment:

(1) The elimination of friction by use of detectors for slipping belts, temperature supervision of moving or impacted surfaces, and so forth
(2) Pressure resistance or maximum pressure containment capability and pressure-relieving capabilities of the machinery or process equipment and of the building or room
(3) The proper classification of electrical equipment for the area and condition
(4) Proper alignment and mounting to minimize or eliminate vibration and overheated bearings
(5) The use of electrically conductive belting, low-speed belts, and short center drives as a means of reducing static electricity accumulation *(See Section 9.3.)*
(6) Power transmitted by belt, chain, or shaft as follows:
    (a) For power transmitted to apparatus within the processing room by belt or chain, a nearly dusttight enclosure of the belt or chain constructed of substantial noncombustible material that should be maintained under positive air pressure
    (b) For power transmitted by means of shafts, shafts that pass through close-fitting shaft holes in walls or partitions

A.7.1.1 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 AIChE Center for Chemical Process Safety, *Guidelines for Hazard Evaluation Procedures*.

A.7.1.2.1(1)(b) The maximum allowable concentration of oxygen is very dependent on the material, its chemical composition, and, in the case of particulate solids, the particle sizes. In addition, with many combustible metals, it is not advisable to completely eliminate oxygen from the transport gas. During transport, particles can be abraded and broken, exposing unoxidized metal (virgin metal) to the transport gas. When

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Table A.6.6.2 Guidance for Area Electrical Classification

Depth of Dust Accumulation (in.)	Frequency	Housekeeping Requirement	Area Electrical Classification
Negligible[a]	N/A	N/A	Unclassified (general purpose)
Negligible to <1/32[b]	Infrequent[c]	Clean up during same shift.	Unclassified (general purpose)
Negligible to <1/32[b]	Continuous/frequent[d]	Clean as necessary to maintain an average accumulation below 1/64 in.[e]	Unclassified; however, electrical enclosures should be dusttight.[f,g]
1/32 to 1/8	Infrequent[c]	Clean up during same shift.	Unclassified; however, electrical enclosures should be dusttight.[f,g]
1/32 to 1/8	Continuous/frequent[d]	Clean as necessary to maintain an average accumulation below 1/16 in.	Class II, Division 2
>1/8	Infrequent[c]	Immediately shut down and clean.	Class II, Division 2
>1/8	Continuous/frequent[d]	Clean at frequency appropriate to minimize accumulation.	Class II, Division 1

Note: For SI units, 1 in. = 25.4 mm.

[a] Surface color just discernible under the dust layer.

[b] 1/32 in. is approximately the thickness of a typical paper clip.

[c] Episodic release of dust occurring not more than about two or three times per year.

[d] Episodic release of dust occurring more than about three times per year or continuous release resulting in stated accumulation occurring in approximately a 24-hour period.

[e] It has been observed that a thickness of about 1/64 in. of a low-density dust is sufficient to yield a small puffy cloud with each footstep.

[f] For example, National Electrical Manufacturers Association (NEMA) 12 or better. Note: Ordinary equipment that is not heat producing, such as junction boxes, can be significantly sealed against dust penetration by the use of silicone-type caulking. This can be considered in areas where fugitive dust is released at a slow rate and tends to accumulate over a long period of time.

[g] Guidance to be applied for existing facilities. For new facilities, it is recommended that the electrical classification be at least Class II, Division 2.

that metal is finally exposed to oxygen-containing air, the rapid oxidation of the virgin metal could produce sufficient heat to ignite the material. It is, therefore, preferable to provide for a low concentration of oxygen in the transport gas stream to ensure the oxidation of virgin metal as it is exposed during the course of transport.

A.7.1.2.1(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 relief duct should be restricted to no more than 20 ft (6 m).

A.7.1.2.1(5) 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.7.1.2.1(6) For information on dust retention and flame-arresting devices, see NFPA 68, *Guide for Venting of Deflagrations*, Section 9.7.

A.7.1.4 Methods of explosion protection using containment, venting, and suppression protect the specific process equipment on which they are installed. For details on deflagration propagation, see Annex E.

A.7.1.4.2(1) Figure A.7.1.4.2(1) illustrates two different designs of chokes.

A.7.1.4.2(2) When rotary valves are installed in both the inlet and the 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.7.1.4.2(2).

A.7.1.4.2(3) Figure A.7.1.4.2(3) illustrates an example of deflagration propagation using mechanical isolation.

A.7.1.4.2(4) Figure A.7.1.4.2(4) illustrates an example of deflagration propagation using flame front diversion.

A.7.1.4.2(5) Figure A.7.1.4.2(5) illustrates an example of deflagration propagation using chemical isolation.

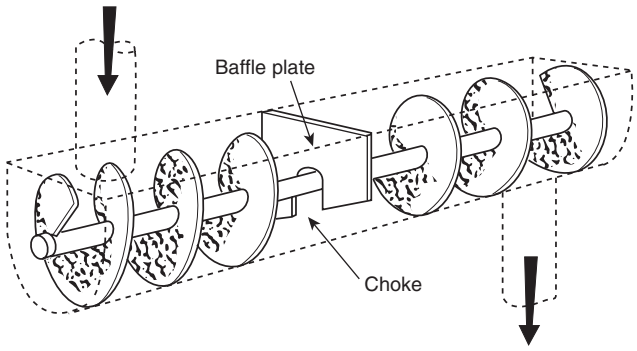
A.7.1.4.4 See A.7.1.1 for an explanation of the considerations in a documented risk evaluation.

A.7.1.5 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 endangers personnel.

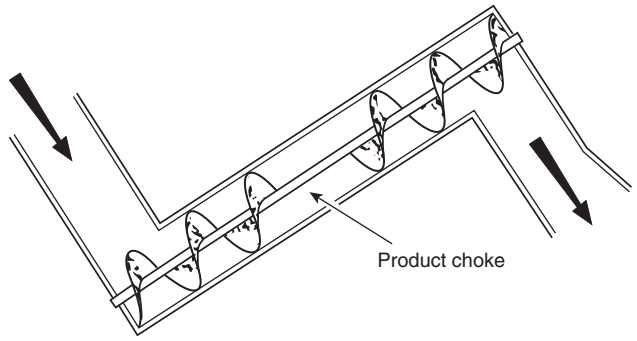
A.7.2.1.2 Shipping containers can pose a deflagration hazard; however, deflagration protection measures for these units are not always practical. Consideration should be given to deflagration hazards when electing to omit deflagration protection.

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Example 1



Example 2

FIGURE A.7.1.4.2(1) Screw Conveyor Chokes.

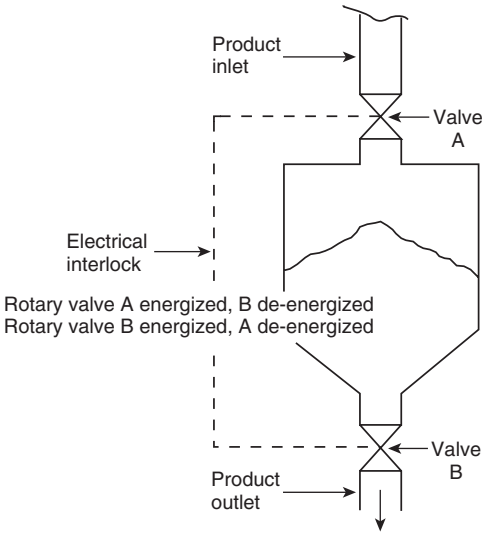


FIGURE A.7.1.4.2(2) Rotary Valves.

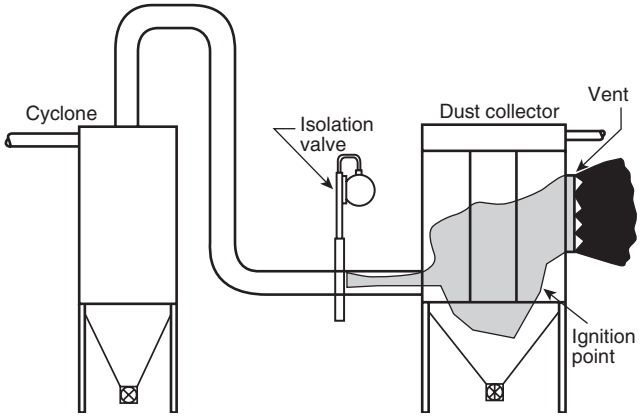


FIGURE A.7.1.4.2(3) Deflagration Propagation Using Mechanical Isolation.

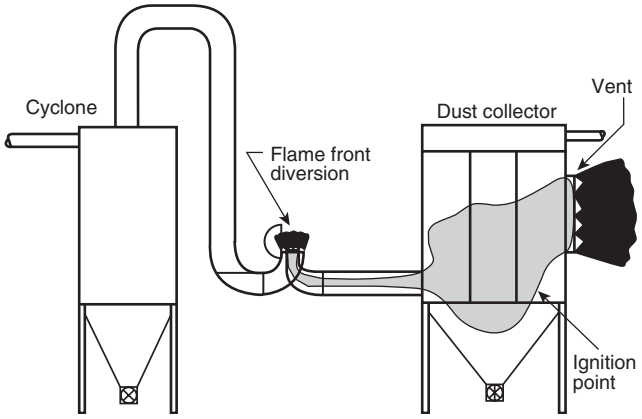


FIGURE A.7.1.4.2(4) Deflagration Propagation Using Flame Front Diversion.

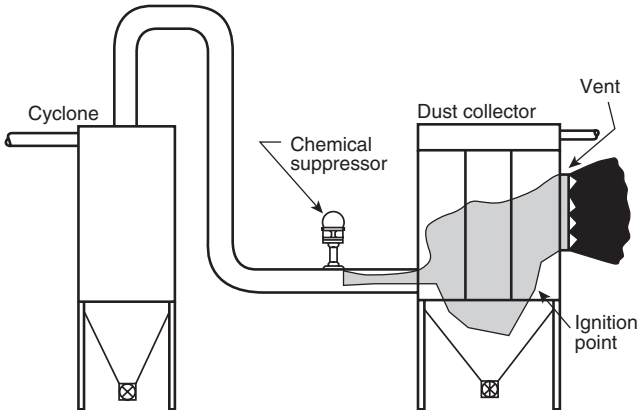


FIGURE A.7.1.4.2(5) Deflagration Propagation Using Chemical Isolation.

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A.7.2.3.2.2(2) Where explosion venting is used, its design should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations*. For explosion relief venting through ducts, consideration should be given to the reduction in explosion venting efficiency caused by the ducts. The ducts should be designed with a cross-sectional area at least as large as the vent. They should be structurally as strong as the enclosure being vented. Because any bends cause increases in the pressure developed during venting, vent ducts should be as straight as possible. If bends are unavoidable, they should be as shallow angled (i.e., have as long a radius) as is practicable.

A.7.2.3.2.2(3) Small containers can pose an explosion hazard; however, explosion protection measures for these units are not always practicable. Consideration should be given to explosion hazards when electing to omit protection.

A.7.2.3.3.3 See A.7.2.3.2.2(3).

A.7.2.4 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.7.2.5 For information on designing deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A.7.3.1.1 For additional information, see ASTM E 2012, *Standard Guide for the Preparation of a Binary Chemical Compatibility Chart*.

A.7.3.2.4 For guidance on determining air volume and air velocity, refer to *Industrial Ventilation — a Manual of Recommended Practice,* published by the American Conference of Governmental Industrial Hygienists (ACGIH).

A.7.3.3.2 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 LFL of the vapor.

A.7.4.1.1 Whether a metallic particulate reacts with water depends on particle size, chemical purity of the particulate, oxygen concentration, and combustion temperature. Consequently, an engineering analysis should be performed prior to selecting an extinguishment strategy. In some cases, a rapidly discharged high-volume water spray system has been shown to be effective, due to the rapid absorption of heat.

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

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

A.7.6.4 Whenever a duct size changes, the cross-sectional area changes as well. This change in area causes a change in air velocity in the region of the change, introducing turbulence effects. The net result is that a transition with an included angle of more than 30 degrees represents a choke when the direction of flow is from large to small and results in localized heating and static electric charge accumulation. When the transition is from small to large, the air velocity drop at the transition is usually enough to cause product accumulation at the transition and the existence of a volume where the concentration of combustible is above the MEC. It is strongly desirable to avoid both situations.

A.7.6.5 Isolation devices in accordance with 7.1.4 are provided to prevent deflagration propagation between connected equipment. According to 7.1.4, additional protection is indicated when the integrity of a physical barrier could 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.7.8.2 For information on deflagration pressure relief, see A.7.1.2.1(2).

A.7.10 It is recommended that bucket elevators be located outside of buildings wherever practicable. Although explosion protection for bucket elevators is required in 7.10.1, an additional degree of protection to building occupants and contents is provided by locating the bucket elevator outside of the building.

A.7.10.1 Deflagration vents on bucket elevators should be distributed along the casing side in pairs, opposite each other, 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 the vents should be located approximately 20 ft (6 m) apart. Vent closures should be designed to open at an internal gauge pressure of 0.5 psi to 1.0 psi (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 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 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 practicable.

A.7.10.4.1 Methods by which this cutoff can be achieved include sensing overcurrent to the drive motor or high motor temperature.

A.7.10.5.2 Where conductive buckets are used on nonconductive belts, bonding and grounding should be considered to reduce the hazards of static electricity accumulation. See NFPA 77, *Recommended Practice on Static Electricity*, for more information.

A.7.10.7 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 both locations.

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A.7.10.8.1 The motor selected should not be larger than the smallest standard motor capable of meeting this requirement.

A.7.11 Explosion protection should be provided when the risk is significant. Where coverings are provided on cleanout, inspection, or other openings, they should be designed to withstand the expected deflagration pressure. *(See 7.1.2.)*

A.7.11.2.1 Methods by which this shutoff can be achieved include sensing overcurrent to the drive motor or high motor temperature.

A.7.12.2.2 Some systems are designed to operate at solids concentrations that pose no fire or deflagration risk. Such systems include nuisance dust exhaust systems and the downstream side of the last air–material separator in the pneumatic conveying system.

A threshold concentration limit of 1 percent of the MEC has been conservatively set to discriminate between such systems and other systems designed to operate at a significant combustible solid loading. This limit ensures that normal variations in processing conditions do 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 could include one of the following:

(1) Secondary filtration (e.g., high-efficiency cartridge filter) between the last air–material separator and the air-moving device
(2) Bag filter failure detection interlocked to shut down the air-moving device

A.7.12.2.3 These systems include pneumatic conveying systems that require relay (booster) fans and product dryers where the fan is an integral part of the dryer.

A.7.13.1.1.2 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. Because any bends cause increases in the pressure that develops 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 practicable.

A.7.13.1.5 For design requirements for fast-acting dampers and valves, flame front diverters, and flame front extinguishing systems, see NFPA 69, *Standard on Explosion Prevention Systems*.

A.7.13.2.3.5 See NFPA 68, *Guide for Venting of Deflagrations*.

A.7.14 Abort gates cannot be relied upon to manage deflagrations. See also Annex C.

A.7.15 Size reduction machinery includes equipment such as mills, grinders, and pulverizers.

A.7.16 Particle separation devices include screens, sieves, aspirators, pneumatic separators, sifters, and similar devices.

A.7.16.3 For information on designing deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A.7.16.3.2 As a practical matter, screens are difficult to protect against explosion by deflagration venting or inerting. Therefore, it is important that screens be isolated from the fire and explosion hazards of the remainder of the process and be adequately protected against electrostatic ignition sources. Protection should be accomplished by bonding and grounding of all conductive components.

A.7.18 Dryers include tray, drum, rotary, fluidized bed, pneumatic, spray, ring, and vacuum types. Dryers and their operating controls should 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.

A.7.18.9 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 of 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 the 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 preceding factors.

The dust cloud ignition temperature can be determined by the method referenced in U.S. Bureau of Mines RI 8798, "Thermal and Electrical Ignitability of Dusts" (modified Godbert-Greenwald furnace, BAM furnace, or other methods). The dust layer ignition temperature can be determined by the U.S. Bureau of Mines test procedure given in Lazzara and Miron, "Hot Surface Ignition Temperatures of Dust Layers."

A.8.2.1 See A.6.2.3.1.

A.8.2.2 Factory Mutual recommends that surfaces should be cleaned frequently enough to prevent hazardous accumulations (FM Data Sheet 7-76, "Operations and Maintenance," 2.3.5).

A.9.1.1.3 Specific attention should be paid to combustible particulate solids where they are introduced into the process stream. Some sources of particulate could include stone, tramp iron, other metallic contaminants, and already burning material. Before a risk management strategy is adopted, both the particulate and the process equipment have to be carefully evaluated.

See Figure A.9.1.1.3(a) and Figure A.9.1.1.3(b) for examples of foreign material removal.

A.9.1.2 If the particulate particle size range includes dusts that can attain concentrations capable of propagating a flame front through a fuel–air mixture, the risk management options in 9.1.2 are appropriate. Conversely, if the analysis indicates that the particle size and concentration do not predict a propagating flame front through the fuel–air mixture, the fire protection methods in Chapter 10 should be considered.

A.9.1.3 Transmission of power by direct drive should be used, where possible, in preference to belt or chain drives.

A.9.1.4 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.

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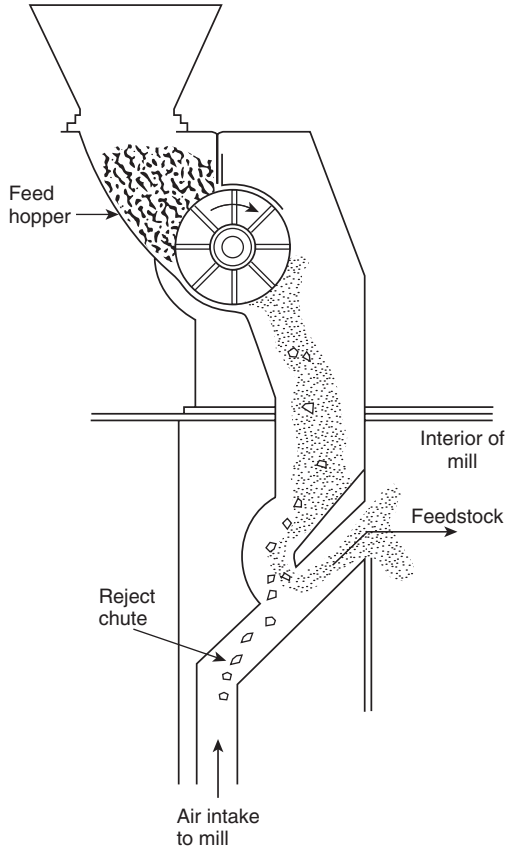


FIGURE A.9.1.1.3(a) Pneumatic Separator.

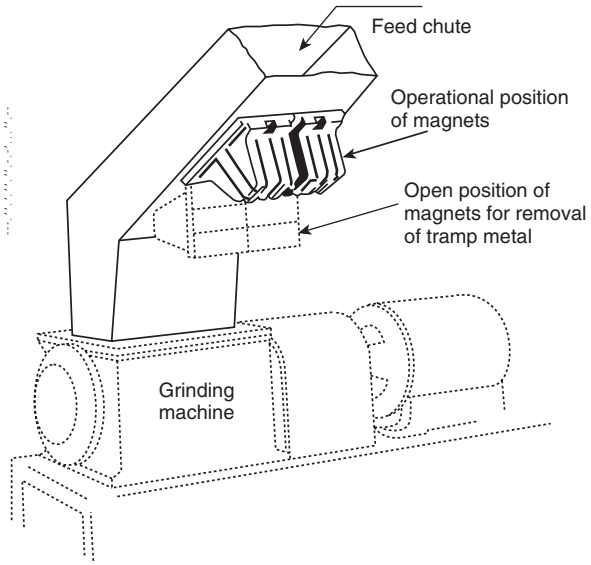


FIGURE A.9.1.1.3(b) Magnetic Separator.

A.9.3 See NFPA 77, *Recommended Practice on Static Electricity*, for information on this subject.

A.9.3.1 Bonding minimizes the potential difference between conductive objects. Grounding minimizes the potential difference between objects and ground.

A.9.3.3.1 For further information regarding the hazards and uses of flexible and rigid intermediate bulk containers, see the following publications:

(1) NFPA 77, *Recommended Practice on Static Electricity*, Section 9.1
(2) Britton, *Avoiding Static Ignition Hazards in Chemical Operations*, pp. 199–204

A.9.3.3.1(2) MIE is measured in accordance with ASTM E 2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.

A.9.3.3.1(3) Suitability of Type C FIBCs for specific atmospheres should be determined by the FIBC manufacturer(s). Failure to provide grounding for a Type C FIBC can create a potential static discharge hazard greater than that created by using Type A or Type B FIBCs.

A.9.3.3.1(4) Suitability of Type D FIBCs for specific atmospheres should be determined by the FIBC manufacturer(s).

A.9.3.3.1(5) For example, emptying velocities are slow enough to prevent electrostatic accumulation, MIEs are sufficiently high to preclude electrostatic ignition, or electrostatic charge generation is sufficiently low.

A.9.3.3.2 Certain fabrics that pose significantly less risk of ignition in flammable atmospheres have been developed for use in FIBCs. One such fabric that has been tested for use in atmospheres having a minimum ignition energy of 0.25 mJ or greater and that has been used in FIBCs is documented in the paper for AIChE presented by Ebadat and Mulligan, "Testing the Suitability of FIBCs for Use in Flammable Atmospheres."

A.9.6.1 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.9.7 The ignition temperature of a layer of dust on hot surfaces could decrease over time if the dust dehydrates or carbonizes. For that reason, the hot surfaces should not exceed the lower of the ignition temperature or 329°F (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.10.2.1 Pneumatic conveying systems that move combustible particulate solids can be classified as water compatible, water incompatible, or water reactive. Inasmuch as water is universally the most effective, most available, and most economical extinguishing medium, it is helpful to categorize combustible particulate solids in relation to the applicability of water as the agent of choice. For details on use of water as an extinguishing agent, see Annex F.

A.10.3.2 Extreme care should be employed in the use of portable fire extinguishers in facilities where combustible dusts are present. The rapid flow of the extinguishing agent across or against accumulations of dust can produce a dust cloud. When a dust cloud is produced, there is always a deflagration hazard. In the case of a dust cloud produced as a result of fire

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fighting, the ignition of the dust cloud and a resulting deflagration are virtually certain.

Consequently, when portable fire extinguishers are used in areas that contain accumulated combustible dusts *(refer to A.6.2.3.1)*, the extinguishing agent should be applied in a manner that does not disturb or disperse accumulated dust. Generally, fire extinguishers are designed to maximize the delivery rate of the extinguishing agent to the fire. Special techniques of fire extinguisher use should be employed to prevent this inherent design characteristic of the fire extinguisher from producing an unintended deflagration hazard.

A.10.5 Automatic sprinkler protection in 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.10.5.1 A risk evaluation should consider the presence of combustibles both in the equipment and in the area around the process. Considerations should include the combustibility of the building construction, the equipment, the quantity and combustibility of process materials, the combustibility of packaging materials, open containers of flammable liquids, and the presence of dusts. Automatic sprinkler protection in dust collectors, silos, and bucket elevators should be considered.

A.11.3.2(8) 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:

(1) A signal or alarm system
(2) Identification of means of egress
(3) Minimization of effects on operating personnel and the community
(4) Minimization of property and equipment losses
(5) Interdepartmental and interplant cooperation
(6) Cooperation of outside agencies
(7) The release of accurate information to the public

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 catastrophic 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.12.1.2(5) 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 AIChE *Guidelines for Safe Automation of Chemical Processes*.

A.12.2.2.4 Periodic cleaning of components is especially important if the blower or fan is exposed to heated air.

A.12.2.2.5 If rust is allowed to form on the interior steel surfaces, it is only a matter of time before an iron oxide (rust) becomes dislodged and is taken downstream, striking against the duct walls. In some cases, this condition could cause an ignition of combustibles within the duct. The situation worsens if aluminum paint is used. If the aluminum flakes off or is struck by a foreign object, the heat of impact could be sufficient to cause the aluminum particle to ignite, thereby initiating a fire downstream.

A.12.2.5.3 For information on maintenance of deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

Annex B Explosion Protection

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

B.1 General. This annex covers the following common methods of explosion protection:

(1) Containment
(2) Inerting
(3) Deflagration venting
(4) Deflagration suppression
(5) Deflagration isolation

B.2 Containment. The basis for the containment method of protection is a process designed 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. The final deformation pressure depends on the maximum initial pressure in the vessel prior to the deflagration. NFPA 69, *Standard on Explosion Prevention Systems*, limits the maximum initial gauge pressure to 30 psi (207 kPa) for containment vessels.

The equipment is designed either to prevent permanent deformation (working below its yield strength) or to prevent 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, its design should avoid flat surfaces and rectangular shapes. The strength of welds and other fastenings should also be considered.

The major advantage of containment is that it requires little maintenance due to its passive approach to explosion protection.

The disadvantages of containment are as follows:

(1) High initial cost
(2) Weight loading on plant structure

B.3 Inerting. Inerting protection is provided by lowering the oxygen concentration, in an enclosed volume, below the level required for combustion. That is achieved by introducing an inert gas such as nitrogen or carbon dioxide. Flue gases can be used, but they could first require cleaning and cooling. *(See* NFPA 69, *Standard on Explosion Prevention Systems.)*

The purge gas flow and oxygen concentration in the process should be designed reliably with appropriate safety factors in accordance with NFPA 69, *Standard on Explosion Prevention Systems*. Consideration should be given to the potential for asphyxiation of personnel due to purge gas or leakage.

The major advantage of inerting is prevention of combustion, thereby avoiding product loss.

The disadvantages of inerting are as follows:

(1) Ongoing cost of inert gas
(2) Possible asphyxiation hazard to personnel
(3) High maintenance

B.4 Deflagration Venting. Deflagration venting provides a panel or door (vent closure) to relieve the expanding hot gases of a deflagration from a process component or room.

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B.4.1 How Deflagration Venting Works. Except for an open vent, which allows flammable gases to discharge directly to the 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 the atmosphere either directly or via a vent duct, resulting 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 process is illustrated in Figure B.4.1.

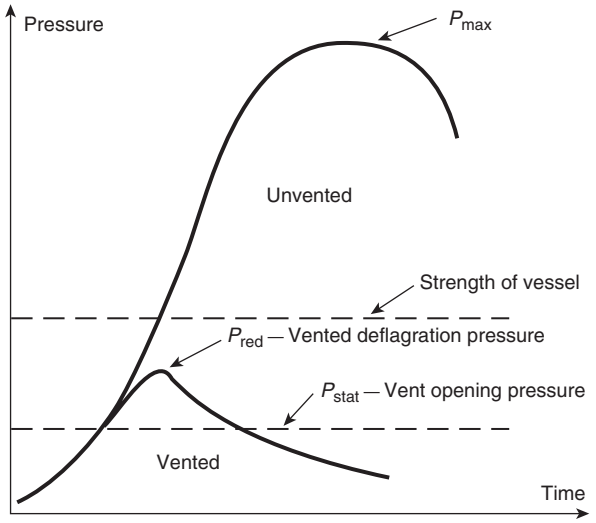


FIGURE B.4.1 Pressure–Time Graph of a Vented Deflagration.

B.4.2 Deflagration Vent Panel. The deflagration vent panel 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 allows 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 could 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.4.2. Such vents are either rectangular or circular.

B.4.3 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, a vent door has a greater inertia than a vent panel, reducing its efficiency.

B.4.4 Applications. Deflagration vents are used for applications that handle gases, dusts, or hybrid mixtures. Typical applications include dust collectors, silos, spray dryers, bucket elevators, and mixers. Figure B.4.4 shows a typical vent panel installation on a dust collector.

The advantages of deflagration venting are as follows:

(1) Low cost, if the process component is located outside
(2) Low maintenance due to use of passive device

The disadvantages of deflagration venting are as follows:

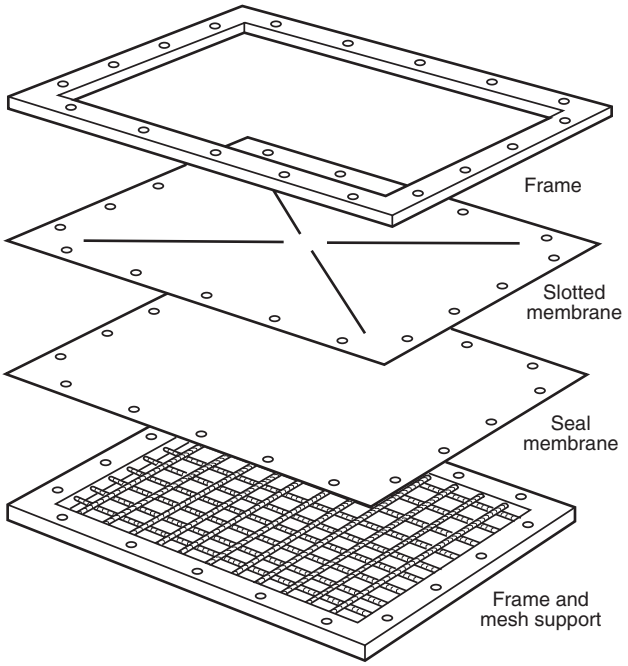


FIGURE B.4.2 Deflagration Vent Panel and Support Grid.

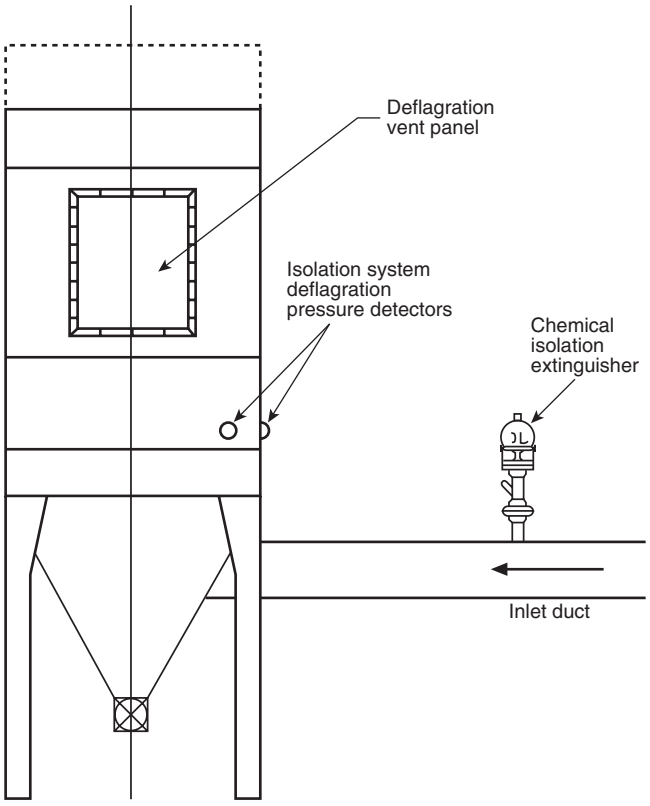


FIGURE B.4.4 Vented Dust Collector.

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(1) The potential for a postventing fire within the component, particularly if combustible materials, such as filter bags, are still present
(2) The recommendation that the plant component be near an outside wall or located outside
(3) 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
(4) Contraindication of the process for toxic or corrosive material

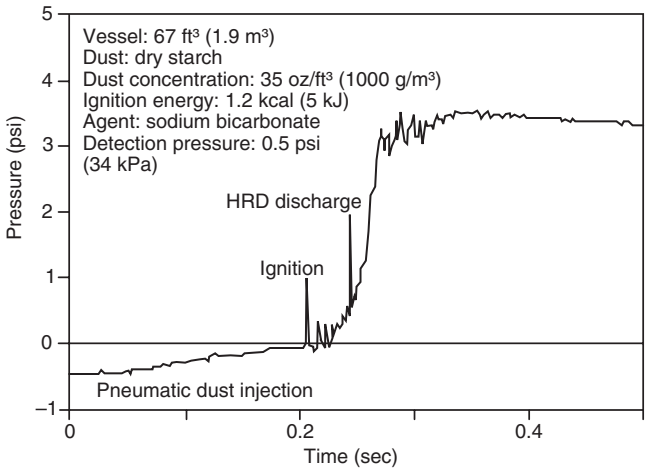
B.4.5 Design Considerations. The following points should be considered in the design and evaluation of the suitability of deflagration venting:

(1) Reaction forces
(2) Postexplosion fires
(3) Material toxicity or corrosiveness
(4) Good manufacturing practices (GMP) (food and pharmaceutical applications)
(5) Vent efficiency
(6) Connections to other process equipment
(7) Vent duct backpressure
(8) Thermal insulation
(9) Safe venting area
(10) Vacuum protection
(11) Location

B.5 Deflagration Suppression. Deflagration suppression involves a high-speed flame-extinguishing system that detects and extinguishes a deflagration before destructive pressures are created.

B.5.1 How Deflagration Suppression Works. An explosion is not an instantaneous event. The growing fireball has a measurable time to create its destructive pressures. Typically the fireball expands at speeds of 30 ft/sec (9 m/sec), whereas the pressure wave ahead of it travels at 1100 ft/sec (335 m/sec). The deflagration is detected either by a pressure detector or a flame detector, and 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.5.1(a).

Because the fireball is suppressed at an early stage, rupture of the vessel is prevented. Figure B.5.1(b) shows the pressure–time graph of the suppression of a starch deflagration in a 67 ft^3 (1.9 m^3) vessel. Note that the reduced deflagration gauge pressure is approximately 3.5 psi (24 kPa) in this test.



Note: Pressures are gauge pressures.

FIGURE B.5.1(b) Pressure Versus Time in a Suppressed Deflagration.

B.5.2 Applications. Deflagration suppression systems are used for applications that handle gases, dusts, or hybrid mixtures. Typical applications include dust collectors, silos, spray dryers, bucket elevators, and mixers. Figure B.5.2 shows a typical suppression system installation on a dust collector.

The advantages of a deflagration suppression system are as follows:

(1) Elimination of flame and reduced chance of subsequent fire
(2) Reduced risk of ejected toxic or corrosive material
(3) Flexibility in process component locations

The disadvantages of a deflagration suppression system are as follows:

(1) Generally higher cost than for deflagration venting
(2) Requirement for regular maintenance
(3) Ineffectiveness for certain metal dusts, acetylene, and hydrogen

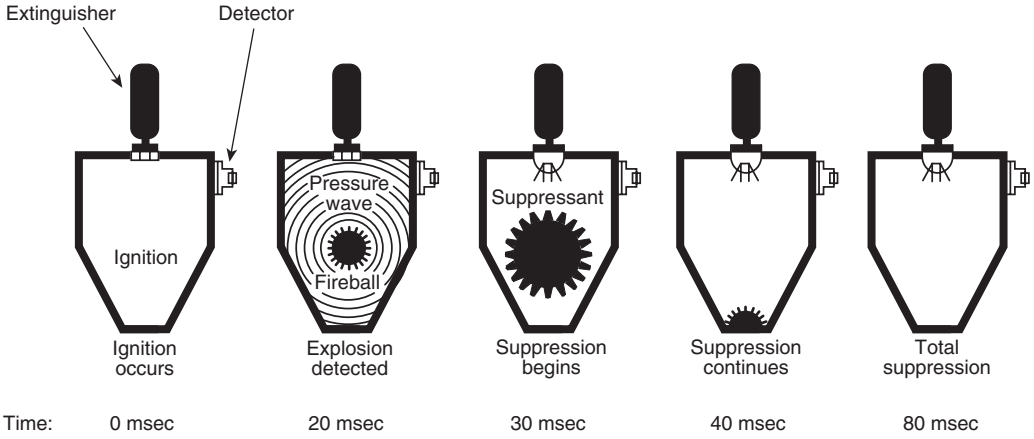


FIGURE B.5.1(a) Deflagration Suppression Sequence of Starch in a 35 ft^3 (1 m^3) Vessel.

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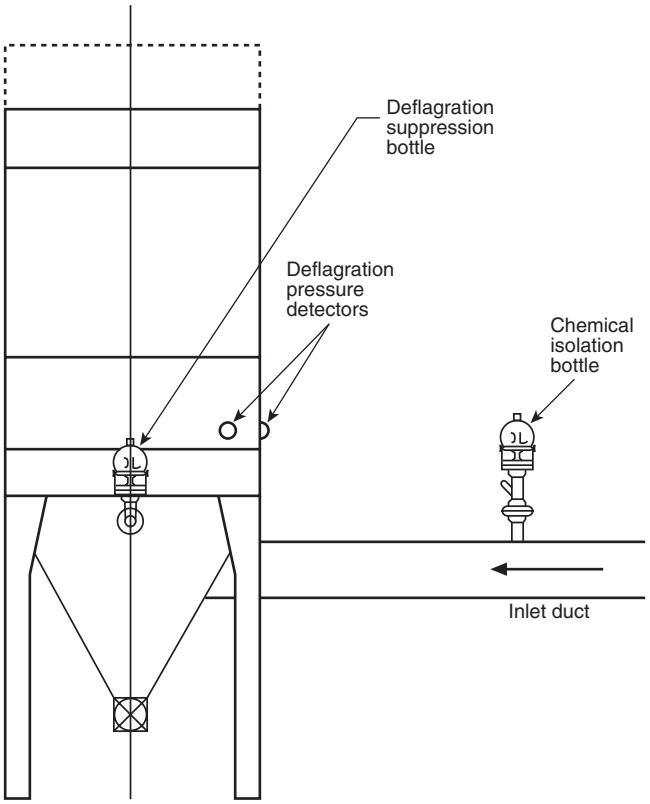


FIGURE B.5.2 Dust Collector Suppression System.

B.5.3 Design Criteria. Deflagration suppression systems are designed in accordance with NFPA 69, *Standard on Explosion Prevention Systems*, and ISO 6184-4, *Explosion Protection Systems — Part 4: Determination of Efficiency of Explosion Suppression Systems*. The following information is required for design of a suppression system:

(1) Process material
(2) K_{St} or K_G, value in psi-ft/sec (bar-m/sec)
(3) Vessel strength
(4) Vessel dimensions and volume
(5) Maximum and minimum operating pressures and temperatures
(6) Connections to other process equipment

B.6 Deflagration Isolation. A process component such as a dust collector or silo could be protected from an explosion by venting, suppression, or containment. However, its connections to other process components by pipes and ducts pose the threat of deflagration propagation. A deflagration vent on a dust collector could save it from destruction, but the inlet duct could still propagate flame to other parts of the plant. Such propagation can result in devastating secondary explosions. The importance of ducts is stated in NFPA 68, *Guide for Venting of Deflagrations*, which says:

Interconnections between separate pieces of equipment present a special hazard.…Where such interconnections are necessary, deflagration isolation devices should be considered, or the interconnections should be vented. [**68:**5.6.7]

Although NFPA 68, *Guide for Venting of Deflagrations*, indicates venting as an option for interconnections, venting is valid only when interconnected equipment is protected from explosions.

The need for isolation is further supported by research that shows that interconnecting vessels can result in precompression of gases in connected vessels caused by a deflagration. The result is that a deflagration in one vessel can produce considerably higher pressures in the connected vessel. Mechanical or chemical isolation methods should therefore be considered where interconnections between vessels are present.

B.6.1 Mechanical Isolation. Mechanical deflagration isolation can be provided by rotary airlock valves of suitable construction. An example of their use is at the discharge of dust collector hoppers. To be effective and to prevent the transmission of flame and burning materials, rotary airlock valves should be stopped at the moment a deflagration is detected. To be truly effective, rotary airlock valves should be integrated into an explosion detection/protection system for the piece of equipment being protected.

Rotary airlock valves for deflagration isolation should be of rugged construction and suitable design. Such design is particularly important for pieces of equipment protected by deflagration venting and containment. This application puts more demand on the integrity of rotary airlock valves than on the components protected by suppression. The reason is that suppression extinguishes the flame in addition to mitigating the pressure.

Another example of mechanical isolation is the high-speed knife gate valve. High-speed gate valves should be capable of withstanding the maximum deflagration pressure. Typically, valves are rated for gauge pressures up to 150 psi (1035 kPa) and should be capable of closing in milliseconds. The pipework also needs to withstand the maximum deflagration pressure, P_{max}. Figure B.6.1 shows a typical arrangement for a high-speed gate valve. A detector, which could be a pressure switch or an optical detector, detects the deflagration pressure or flame front. The trigger then initiates the rapid valve closure to prevent the propagation of flame and pressure. If the connected piece of equipment is protected by deflagration venting or deflagration suppression, then little pressure can be expected. In such cases, the valve that isolates a connected pipe can be replaced by a chemical isolation barrier.

B.6.2 Chemical Isolation. Chemical isolation is achieved by the rapid discharge of a chemical extinguishing agent into the interconnecting pipe or duct. Figure B.6.2 shows a typical arrangement for chemical isolation. A deflagration detector, which could be a pressure switch or an optical detector, detects the deflagration pressure or flame front. The trigger then initiates the rapid discharge of extinguishing agent from a high-speed extinguisher bottle, thus preventing the propagation of flame and burning materials.

Chemical deflagration isolation should not be confused with ignition source (spark) suppression systems. Such systems are intended to detect burning particles traveling down a duct and extinguish them with a downstream spray of water. They are not designed to stop deflagrations once they have started and are ineffective for preventing deflagration propagation through interconnected equipment.

B.7 Limitations of Flame Front Diverters. Flame front diverters can divert deflagration flames by directing them to the atmosphere. However, these devices do have limitations. If the air-moving device is located downstream of the flame front

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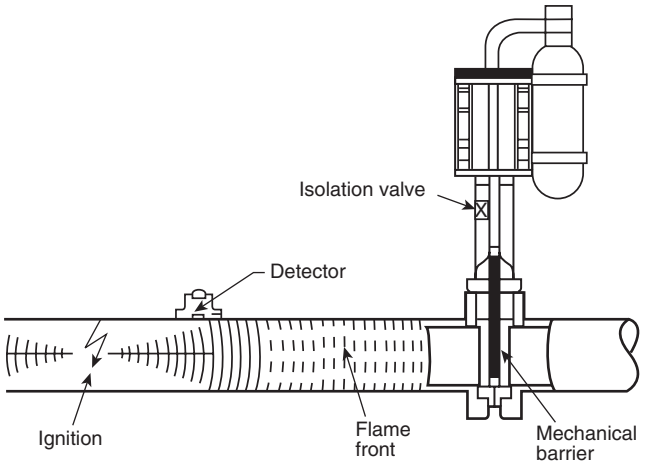


FIGURE B.6.1 Mechanical Isolation Using a High-Speed Gate Valve.

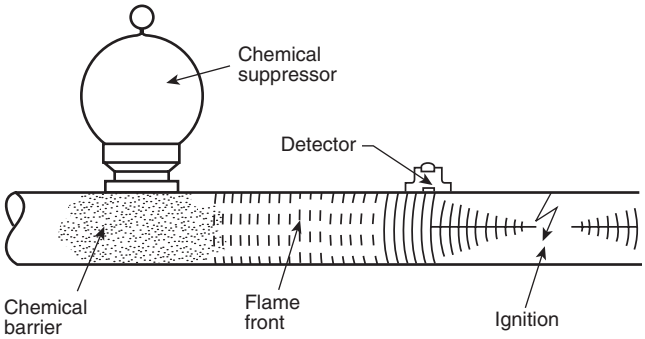


FIGURE B.6.2 Typical Arrangement of Chemical Isolation.

diverter, an explosion originating upstream of the diverter can propagate past it because of the deflagration flames being sucked into the downstream side, despite the open diverter cover. Also, tests suggest that some diverters could be ineffective in completely diverting a deflagration involving a hybrid mixture whose vapors exceed the LFL, regardless of the location of the air-moving device. Nevertheless, in both situations where a flame front diverter allows propagation, the deflagration severity in the system is expected to be reduced.

Annex C Informational Primer on Spark Detection and Extinguishing Systems

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

C.1 Primer Design Concepts for Spark Detection and Extinguishing Systems.

C.1.1 Spark/Ember Detectors. Spark/ember detectors are radiant energy–sensing fire detectors. The design, installation, and maintenance of radiant energy–sensing fire detectors are covered in Chapter 5 of *NFPA 72, National Fire Alarm Code.* Where required by NFPA 654, spark detectors are used to actuate an abort gate to divert fuel, flames, and combustion gases to a safe location.

However, spark detectors are more commonly integrated into a spark detection and extinguishing system. In this second case, the extinguishment is usually an intermittent water spray designed and installed pursuant to NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, and maintained pursuant to NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.* Because the overwhelming majority of the applications that employ spark/ember detectors are pneumatic conveying systems, it is appropriate to provide a primer on these devices as part of this standard.

C.1.1.1 Actuation of Abort Gate. When spark detectors are used to actuate an abort gate, the design concepts are fairly straightforward. The detectors are mounted on the duct upstream from the abort gate and are wired to a control panel listed and approved for that purpose. When a detector senses a spark, the signal causes the control panel to alarm, and the solenoid or other releasing device on the abort gate is energized. This type of system is shown in Figure C.1.1.1.

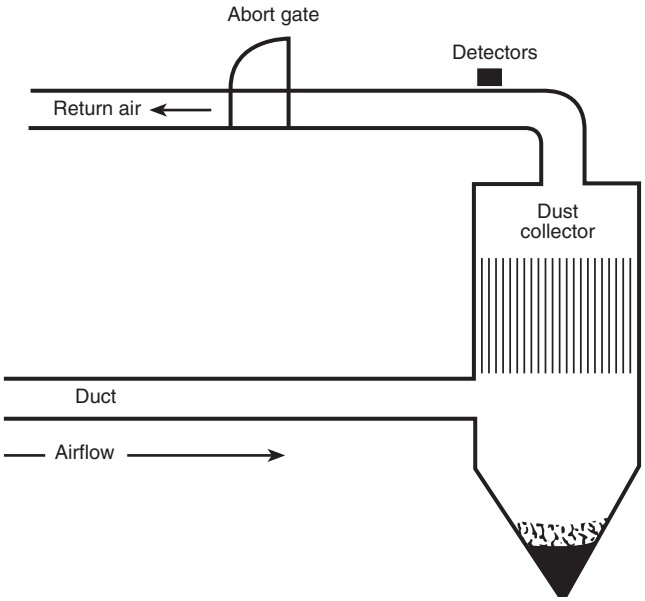


FIGURE C.1.1.1 Spark Detectors and Abort Gate.

C.1.1.2 Spark Detection and Extinguishing Systems. Spark detection and extinguishing systems usually consist of a group of detectors that are located on the conveying duct, a control panel in a safe accessible location, and an extinguishment solenoid valve and nozzle set located on the duct downstream from the detectors. Such a system is shown in Figure C.1.1.2.

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

C.1.2 Critical Design Concepts. For both system design concepts, several critical factors should be addressed if they are to

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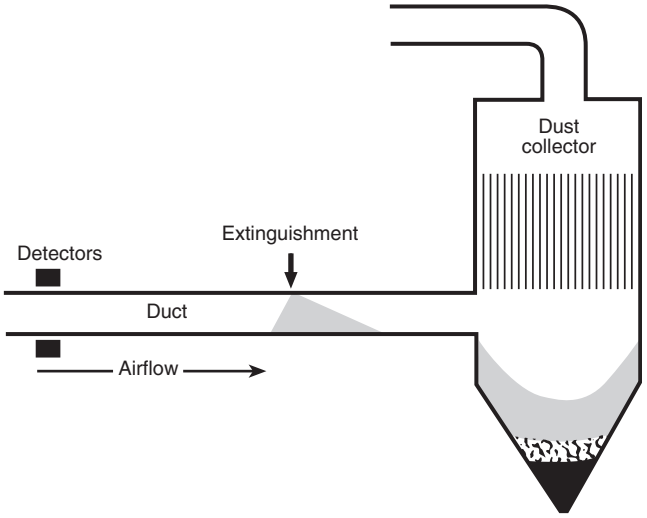


FIGURE C.1.1.2 Typical Spark Detection and Extinguishing System.

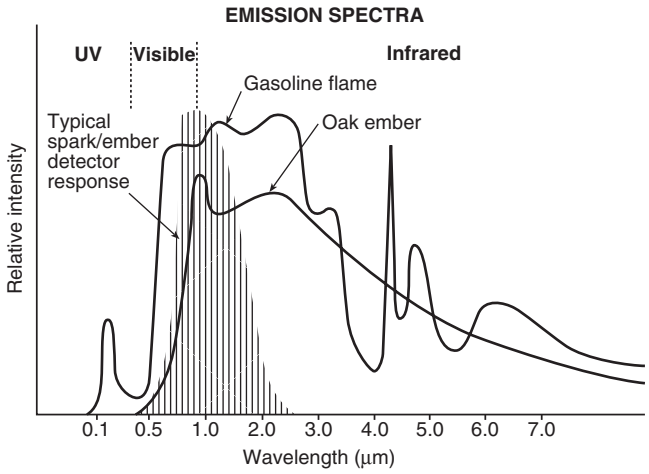


FIGURE C.1.2.1 Emissions of an Oak Ember and Gasoline Flame Compared to the Spectral Sensitivity of a Spark/Ember Detector.

work. First, the detector should be able to reliably detect a spark, an ember, or a flame. Second, the alarm signal should be processed quickly. The timing should be predictable enough to allow the abort gate to operate or to allow the extinguishing system sufficient time to establish the water spray. Finally, in the case of the extinguishing system, there should be a provision to reapply the water spray extinguishment repetitively. The occurrence of an individual, isolated spark is rare; usually sparks are produced in a burst or stream. The extinguishing system should be able to reactivate as each successive spark is detected. Unless all these concerns are addressed, spark/ember detection and extinguishment cannot be used as usually supplied.

C.1.2.1 Spark Detector Reliability. The first concern regarding a spark/ember detector is its ability to detect a spark, ember, or fire. *NFPA 72, National Fire Alarm Code,* defines a spark as "a moving ember" and defines an ember as "a particle of solid material that emits radiant energy due either to its temperature or the process of combustion on its surface." Figure C.1.2.1 shows the radiation intensity as a function of wavelength for an oak ember and a gasoline flame.

The spectral sensitivity of the typical spark/ember detector is superimposed on the graph in Figure C.1.2.1. One can see that the spark/ember detector will sense the radiation from both an ember (spark) and a flame.

C.1.2.2 Detector Sensitivity and Speed. The second concern regarding the detectability of a spark or flame in a duct is the sensitivity and speed of the detector. Because the detector is designed to be mounted on a duct that is dark, silicon photodiode sensors can be used, and there will be few, if any, sources of spurious alarm within the duct. The sensors allow the detectors to be made both extremely sensitive and extremely fast. Sensitivities of 1.0 μW and speeds of 100 microseconds are common. The result is a detector that can detect a spark the size of a pinhead moving faster than the speed of sound. The outcome is that both sparks and flames are easily detected in pneumatic conveying systems with modern spark/ember detectors.

CAUTION: Spark/ember detectors are motion sensitive. If the fire is moving too slowly, the typical spark/ember detector might not detect it. In general, spark/ember detectors do not detect a stationary ember or flame.

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

The arrival time of the spark is a function of the conveying system air speed and the distance between the detector and the extinguishing system. Most spark detection and extinguishing systems provide designers a formula to compute the required distance between the detectors and the abort gate or extinguishment. Generally, it is in the following form:

$$\begin{pmatrix}\text{Air}\\ \text{speed}\end{pmatrix}\times\begin{pmatrix}\text{System}\\ \text{factor}\end{pmatrix}=\begin{matrix}\text{Distance between detectors}\\ \text{and extinguishment}\end{matrix}$$

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

C.1.2.3 Control Panel Design. The third concern regarding these systems involves the extinguishing component. Because the cause of the first spark usually causes additional sparks, the control panel should be designed for the successive and repetitive reapplication of the extinguishing agent. This type of function is not found in the average fire alarm control panel. Specially designed control panels for spark detection and extinguishment are the norm.

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C.2 System Basics.

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

C.2.2 Dual Detectors. Because spark detectors have limited fields of view, most systems require two detectors to cover a round duct. The detectors are usually situated on the inlet to the collector, as shown in Figure C.2.1. This system is the only type of spark detection system required by this standard. However, because it is a minimum compliance standard, additional measures are allowed.

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

C.2.4 Approach to Minimize Shutdowns. The use of a spark detection and extinguishing system on the inlet to the dust collector is an extremely effective way of preventing production stoppages. This type of system mounts a second zone of spark detectors on the pneumatic conveying duct far enough upstream to allow the installation of an intermittent water spray extinguishing system on the inlet duct prior to entry into the primary dust collector (air–material separator). This spark detection and extinguishing system quenches each spark as it comes down the duct, before it reaches the air–material separator. A properly designed and installed spark detection and extinguishing system is very effective in preventing ignitions in the air–material separator. The spark detector that actuates the abort gate is moved to the outlet of the air–material separator, providing a secondary detection. This type of system is shown in Figure C.2.4.

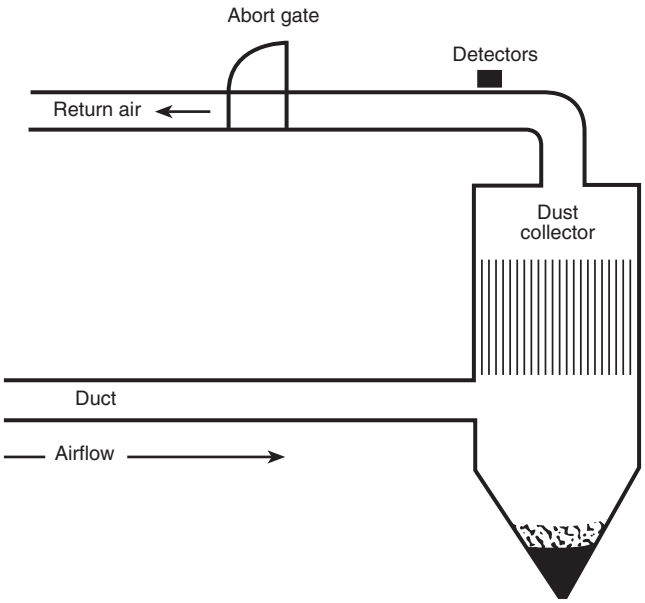


FIGURE C.2.1 Minimum Compliance Spark Detection System.

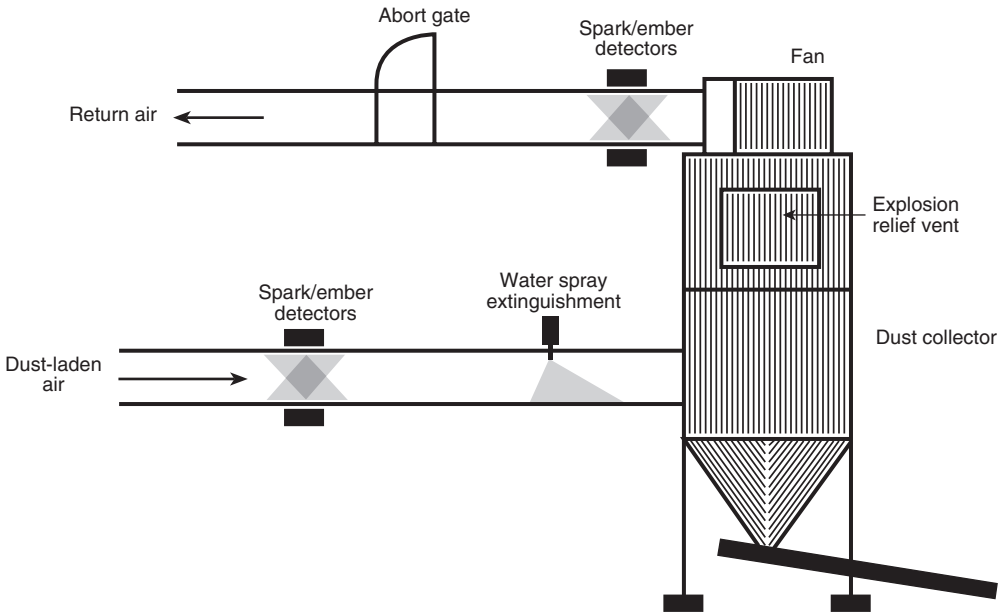


FIGURE C.2.4 Basic Spark Detection and Extinguishing System for a Single Air–Material Separator.

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C.2.5 Additional System Features. The spark detection and extinguishing system involves more than just detectors and a water spray. To provide the degree of performance necessitated by the application, the system should require a number of additional system attributes.

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

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

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

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

Annex D Dust Layer Characterization and Precautions

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

D.1 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 and 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 situation is idealized; 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 material is still sufficient 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. The same 100 ft^2 (9.3 m^2) area in a 2025 ft^2 (188 m^2) building is a moderate hazard. The hazardous 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.

D.2 From the information in Section D.1, the following guidelines can be used to establish a cleaning frequency:

(1) 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].
(2) The dust layer is capable of creating a hazardous condition if it exceeds 5 percent of the building floor area.
(3) 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.
(4) 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.
(5) Due consideration should be given to dust that adheres to walls, since it is easily dislodged.
(6) Attention and consideration should also be given to other projections such as light fixtures, which can provide surfaces for dust accumulation.
(7) 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.

Annex E Deflagration Propagation Isolation Methods

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

E.1 Flame fronts from a deflagration can propagate through connecting ductwork to other unprotected process equipment and to the building from outside process equipment. Figure E.1 shows an example of how such propagation could occur. Isolation techniques as shown in Figure A.7.1.4.2(3), Figure A.7.1.4.2(4), and Figure A.7.1.4.2(5) can be used to prevent the propagation of the deflagration by arresting the flame front.

Both the direction and the extent of potential deflagration propagation should be considered. Usually, a dust deflagration occurs in a fuel-rich regime (i.e., above the stoichiometric fuel–air ratio), making it likely that the initial deflagration will expand into volumes many times greater than the initial deflagration volume.

E.2 The dynamics of a dust explosion are such that unburned dust is pushed ahead of the flame front by the expanding products of combustion. The unburned dust is expelled from the containment vessel via every available exit path, in all possible directions of flow, including flow via all connecting ducts, and out through any provided explosion venting. The driving

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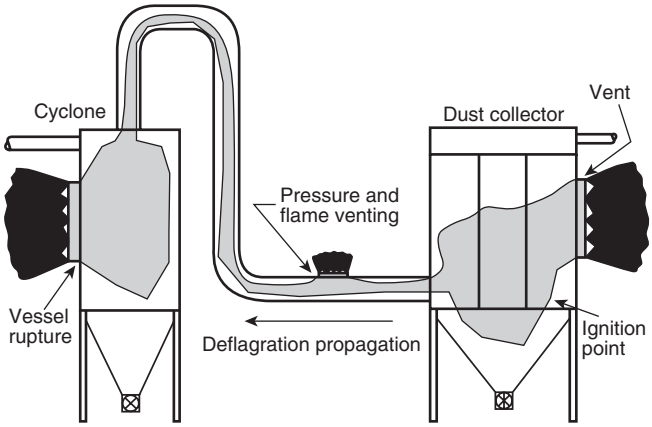


FIGURE E.1 Deflagration Propagation Without Isolation.

force pushing the dust away from the point of initiation [which, under vented conditions, could be in the range of only a few pounds per square inch (kilopascals)] can easily overcome the force of normal system flow (which typically could be of the order of a few inches water column). Furthermore, the velocities produced by the deflagration usually greatly exceed those of the pneumatic conveying system under normal design conditions. Consequently, unburned dust and the deflagration flame front can be expected to propagate upstream through ductwork from the locus of the initial deflagration.

E.3 The conveyance of the flame front via both the infeed and outflow ducts should be evaluated. In most cases, the movement of dust and propagating flame front commutes the deflagration to the connected equipment via ductwork. Where equipment and ducts are adequately protected pursuant to this standard and NFPA 68, *Guide for Venting of Deflagrations* (when explosion venting is used), the consequences of explosion propagation might not increase the life safety hazard or significantly increase property damage. In other cases, however, the transit of a deflagration flame front does result in substantial increases in the severity of an event.

E.3.1 In the case of several pieces of equipment connected via ductwork, where each piece of equipment and the ductwork are provided with explosion venting, the dust explosion can nevertheless propagate throughout the system. Explosion venting on the equipment of deflagration origin prevents overpressure damage to that vessel. If the concentration within the connecting ductwork is below the MEC prior to the deflagration, the deflagration can still spread to the next vessel, but the explosion venting there should protect that second vessel from overpressure damage. In such a case, the provision of explosion isolation would not provide any significant reduction in either the property damage or life safety hazard.

E.3.2 If the concentration within a connecting duct is above the MEC prior to the deflagration, then the propagation through that duct results in an accelerating flame front. Without explosion venting on the ductwork, the accelerating flame front results in a significant prepressurization of the equipment at the other end of the duct and in a powerful jet flame ignition of a dust deflagration in that second vessel. Such a deflagration can overwhelm the explosion venting on that vessel, even if the design is based on information in NFPA 68, *Guide for Venting of Deflagrations*, resulting in the catastrophic rupture of the vessel. In that case, the explosion propagation results in a significant increase in property damage and, quite possibly, in an increase in life safety hazard due to the vessel rupture. Consequently, explosion isolation is a critical component to the management of the fire and explosion risk.

E.3.3 In the case of a dust collector serving a large number of storage silos, an explosion originating in the dust collector can produce an acceptable level of damage to the collector if it is provided with adequate explosion venting per NFPA 68, *Guide for Venting of Deflagrations*. However, the propagation of that explosion upstream to all the connected silos could cause ignition of the material stored in all those silos. The initiation of such storage fires can significantly escalate the magnitude of the incident, in terms of property damage, interruption to operations, and life safety hazard. As with the example in E.3.2, explosion isolation would be warranted in this case.

Annex F Use of Water as Extinguishing Agent for Combustible Particulate Solids

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

F.1 As noted in A.10.2.1, the classification of combustible particulate solids according to their behavior with water affects the effectiveness of water as an extinguishing medium.

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

(1) Wood dusts, fibers, chips, shavings, and flakes
(2) Some paper dusts, depending on ultimate use
(3) Municipal solid wastes (MSWs), including refuse-derived fuels (RDFs)
(4) Coal chunks, pellets, and dusts
(5) Shredded plastic and papers at recycling facilities
(6) Many plastic powders and pellets
(7) Pulverized cork used in a flooring product's manufacturing process
(8) Conveyed agricultural commodities such as oilseeds, walnut shells, and cocoa beans in a deshelling operation
(9) 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 the 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 the 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.

In numerous drying, chopping, crushing, and grinding operations, the introduction of water does not represent a serious threat to the transported material or to the process equipment. For example, in woodworking plants, the wood waste is usually sold as raw material for particleboard or is used as fuel to heat the facility. The moisture from the operation of an extinguishing system is of no consequence. That allows the use of spark detection and intermittent water spray as the fire protection strategy. For other applications, a water deluge system

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is a more appropriate fire protection strategy even though it could disrupt the normal flow of material or interrupt the process operation.

F.2 In contrast, in water-incompatible systems, the introduction of water causes unacceptable damage to the equipment or to the material being processed. In these systems, the particulate solids are combustibles that can be extinguished with water but dissolve in water or form a mixture with it that renders them no longer processable, or the process equipment cannot tolerate the introduction of water. Water-incompatible solids include the following materials:

(1) Cotton fibers (due to the resultant equipment damage from water discharge)
(2) Many foodstuffs such as sugar, flour, spices, cornstarch, and yeasts
(3) Grains and cereals
(4) Tobacco
(5) Many pharmaceuticals
(6) Many chemicals

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

An example of a water-incompatible system is one involving flour. A spray of water into a pneumatic conveying duct that transports flour can extinguish a spark, but the water will combine with the flour to form a paste that can clog the system and promote fermentation. Consequently, there is an operations-based incentive to consider alternatives to water-based extinguishing systems.

F.3 Water-reactive materials chemically react with water to produce some other material that could represent a different set of fire protection problems. The most notable water-reactive materials 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, given that 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 produce either a fire or a toxic or corrosive by-product when mixed with water.

Often an inerted system is 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, could be incompatible with certain metals at high temperatures.

F.4 In summary, a combustible particulate solid should be classified only 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.

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