NFPA 655

Standard for

Prevention of Sulfur Fires and Explosions

2007 Edition

This edition of NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*, was prepared by the Technical Committee on Handling and Conveying of Dusts, Vapors, and Gases. It was issued by the Standards Council on July 28, 2006, with an effective date of August 17, 2006, and supersedes all previous editions.

This edition of NFPA 655 was approved as an American National Standard on August 17, 2006.

Origin and Development of NFPA 655

This standard was first presented to the Association as a progress report in 1938 by the Committee on Dust Explosion Hazards. It was tentatively adopted in 1939. After some revision, it was officially adopted in 1940. Amendments were adopted in 1946, 1947, 1959, 1968, and 1971.

In 1976, responsibility for the document was transferred to the Technical Committee on Fundamentals of Dust Explosion Prevention and Control. The Technical Committee completely revised the 1971 edition to effect minor technical amendments and to editorially revise the document to comply with the NFPA *Manual of Style*.

Due to limited technological changes in this subject area between 1982 and 1988, the Committee reconfirmed the text as it had appeared in the 1982 version. Editorial changes and changes to allow the document to adhere more closely to the 1986 edition of the NFPA *Manual of Style,* were incorporated into the 1988 edition.

For the 1993 edition, the Committee made minor revisions to Chapter 2 for handling finely divided sulfur in bulk and minor revisions to the fire-fighting procedures to be used when fighting fires involving sulfur.

The 2001 edition contained editorial changes associated with incorporation of the 2000 edition of the *Manual of Style for NFPA Technical Committee Documents*. The Committee also made minor revisions to Chapter 6 to address operating precautions for pits and tank sections and to clarify protection for covered liquid sulfur storage tanks.

The 2007 edition includes a complete revision of the standard, which is highlighted by the addition of three new chapters and the revision of Chapter 4, which combines the requirements applicable to both finely divided and coarse sulfur. These chapters reflect the Committee's efforts to expand the dust hazard control requirements within the standard. The new chapters — Chapter 7, Fugitive Dust Control and Housekeeping; Chapter 8, Training and Procedures; and Chapter 9, Inspection and Maintenance — are based upon dust hazard evaluation and control processes found in 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 also contains new requirements applicable to intermediate bulk containers (IBCs).

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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.

NFPA 655
Standard for
Prevention of Sulfur Fires and Explosions
2007 Edition

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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 B. 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 B.

Chapter 1 Administration

1.1 Scope.

1.1.1* This standard shall apply to the crushing, grinding, or pulverizing of sulfur and to the handling of sulfur in any form.

1.1.2 This standard shall not apply to the mining of sulfur, recovery of sulfur from process streams, or transportation of sulfur.

1.2 Purpose.

The purpose of this standard shall be to provide requirements to eliminate or reduce the hazards of explosion and fire inherent in the processing and handling of sulfur.

1.3 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.

1.3.1 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.

1.3.2 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.

1.3.3 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.

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

1.4 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.

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

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

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

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

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

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

NFPA 72®, *National Fire Alarm Code®,* 2007 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2007 edition.

NFPA *101*®, *Life Safety Code*®*,* 2006 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 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment,* 2003 edition.

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

2.3 Other Publications.

2.3.1 ISA Publications.

The Instrumentation, Systems, and Automation Society, 67 Alexander Drive, Research Triangle Park, NC 27709.

ISA S84.01, *Application of Safety Instrumented Systems for the Process Industries,* 2004 edition.

2.3.2 Other Publications.

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

2.4 References for Extracts in Mandatory Sections.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 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 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 Dust Collector. Any device designed to separate the conveying gas stream from the solid being conveyed.

3.3.2* Dust Explosion Hazard. Areas where dust accumulations exceed $\frac{1}{32}$ in. (0.8 mm) or areas where dust clouds of a hazardous concentration exist.

3.3.3 Intermediate Bulk Containers.

3.3.3.1 Flexible Intermediate Bulk Container (FIBC).

3.3.3.1.1 Type A FIBC. A standard insulating flexible intermediate bulk container (FIBC).[**654,** 2006]

3.3.3.1.2 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. [**654,** 2006]

3.3.3.1.3 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. [**654,** 2006]

3.3.3.1.4 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. [**654,** 2006]

3.3.3.2* 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. [**654,** 2006]

3.3.3.2.1 Insulating RIBC. An RIBC constructed entirely of solid plastic or solid plastic and foam composite that cannot be electrically grounded. [**654,** 2006]

3.3.4 Machinery.

3.3.4.1 Type 1. Low-speed primary crushers, such as jaw and roll crushers.

3.3.4.2 Type 2. High-speed primary crushers, such as disk and hammer mills, pulverizers, and fine grinding equipment of all kinds, except Type 4, having a net internal volume of not more than 500 in.^{3} (8193 cm^3).

3.3.4.3 Type 3. Crushers and pulverizers of the Type 2 category, but having an internal volume of more than 500 in.^{3} (8193 cm^3).

3.3.4.4 Type 4. Pulverizers that do not depend on moving parts for their disintegrating action, such as attrition mills.

3.3.5* Sulfur Dust. Finely divided sulfur that presents a fire or deflagration hazard when suspended in air or other oxidizing medium over a range of concentrations regardless of particle size or shape.

Chapter 4 Handling Solid Sulfur in Bulk

4.1 General.

4.1.1 This chapter shall apply to handling and processing of solid sulfur at grinding facilities.

4.1.2 For the purpose of this standard, machinery for crushing and pulverizing sulfur shall be grouped into the following categories:

(1) *Type 1.* Low-speed primary crushers, such as jaw and roll crushers

(2) *Type 2.* High-speed primary crushers, such as disk and hammer mills, pulverizers, and fine grinding equipment of all kinds, except Type 4, having a net internal volume of not more than 500 in.^{3} (8193 cm^3)

(3) *Type 3.* Crushers and pulverizers of the Type 2 category, but having an internal volume of more than 500 in.^{3} (8193 cm^3)

(4)* *Type 4.* Pulverizers that do not depend on moving parts for their disintegrating action, such as attrition mills

4.1.3 Operation and maintenance of all crushing and pulverizing machinery shall be under supervision.

4.2 Location, Construction, and Venting of Buildings and Equipment.

4.2.1 Building Construction.

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

4.2.1.2 Where local, state, and national building codes are more restrictive, modifications shall be permitted for conformance to these codes.

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

4.2.1.4 Spaces inaccessible to housekeeping shall be sealed in order to prevent dust accumulation.

4.2.1.5 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*.

4.2.1.6 Fire Doors.

4.2.1.6.1 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.

4.2.1.6.2 Fire doors shall be installed according to NFPA 80, *Standard for Fire Doors and Other Opening Protectives*, and shall normally be in the closed position.

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

4.2.1.8 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.

4.2.1.9 Fire Resistance Rating.

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

4.2.1.9.2 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.

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

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

4.2.2 Location of Crushing or Pulverizing Machinery and Containers.

4.2.2.1 Where crushing or pulverizing machinery is located in an enclosed or partially enclosed space, that space shall be used only for the size reduction process and the filling of containers with the reduced material when size reduction of sulfur is in progress.

4.2.2.2* Containers shall be removed from the area as soon as possible after being filled.

4.2.3 Building Construction Requirements for Housing Grinding or Pulverizing Machinery.

4.2.3.1 Where Type 1 equipment is located outdoors, it shall be permitted to transfer reduced material in enclosed downstream equipment, provided either of the following conditions exists:

(1) The transferred material is continuously wetted with water sufficient to prevent ignition.

(2) An inert gas isolation system is provided between the Type 1 equipment and the enclosed downstream equipment.

4.2.3.2* Where grinding or pulverizing machinery is located in an enclosed or partially enclosed space, that space shall be separated from other areas by noncombustible construction.

4.2.3.3 The separating walls shall be designed to withstand the force of a sulfur dust explosion.

4.2.3.4 Openings through floors, walls, and ceilings for necessary pipes, shafts, and conveyors shall be sealed dusttight. *(See 4.2.4.1.)*

4.2.4 Protection of Openings.

4.2.4.1 All pathways between the space used for grinding and the rest of the building shall be from the outside or via indirect means as described in 4.2.4.2.

4.2.4.2* Indirect pathways through separating walls by means of vestibules or stairways shall be permitted, provided the wall opening to the grinding area is protected by an automatic-closing fire door suitable for 3-hour openings, and the opening into the vestibule or stairway is protected by an automatic-closing fire door suitable for 2-hour openings.

4.2.4.2.1 The two automatic-closing fire doors shall be installed at right angles to each other.

4.2.4.2.2 Both fire doors shall be installed in accordance with NFPA 80, *Standard for Fire Doors and Other Opening Protectives*.

4.2.5* Buildings housing operations that present a dust explosion hazard shall be designed with explosion venting.

4.2.6 Horizontal Surfaces.

4.2.6.1 All ledges and surfaces on which dust can accumulate shall be avoided in construction.

4.2.6.2 Where such surfaces cannot be avoided, they shall be filled in or roofed with noncombustible material at an angle of not less than 45 degrees.

4.2.7 Explosion Protection for Equipment. 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*, and Section 4.4 of this standard.

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

(b)* When 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*

4.2.8* Isolation of Equipment.

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

4.2.8.2 Isolation devices shall include, but 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*

4.2.8.3 Isolation devices shall not be required when oxidant concentration has been reduced or when the dust has been rendered noncombustible in accordance with 4.2.7(1).

4.2.8.4* 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.

4.3* Electrical Wiring and Equipment.

4.3.1 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*.

4.3.2* 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 of NFPA 70, *National Electrical Code*, as applicable.

4.3.3 Hazardous (classified) areas that are identified in accordance with 4.3.2 shall be documented, and such documentation shall be permanently maintained on file for the life of the facility.

4.4 Inert Gas.

4.4.1 Use of inert gas shall not be required for Type 1 machinery.

4.4.2 Type 2 machinery shall be permitted to be operated without inert gas protection if the following requirements are met:

(1)* The feed and discharge shall be provided with positive chokes, such as a star feed rotary valve or a screw conveyor with some flights removed, where directly connected to the machine.

(2) The chokes and all machinery between them shall be capable of withstanding an overpressure of 100 lb/in.^{2} (690 kPa).

(3) An inspection of the machinery shall be performed at least once per shift during operation to detect abnormalities in operating conditions.

4.4.3 Type 3 Machinery.

4.4.3.1 Type 3 machinery shall not be operated without the use of an inert gas system meeting the requirements of NFPA 69, *Standard on Explosion Prevention Systems*.

4.4.3.2 Where the pulverized sulfur is removed from the machinery by blower or exhaust systems, inert gas protection shall extend to all piping and collectors.

4.4.3.3* The inert gas system shall be equipped with sampling and recording instruments to obtain a reliable and continuous analysis of the inert atmosphere in that part or parts of the machinery where the inert atmosphere is normally weakest.

4.4.3.4 Provisions shall be made for automatically shutting down the pulverizing machinery if the oxygen content of the atmosphere inside the inerted equipment rises above the maximum levels stated in NFPA 69, *Standard on Explosion Prevention Systems*.

4.4.3.5 Under normal operating conditions, the limiting oxygen concentration (LOC) shall be permitted to be as follows:

(1) 12.0 percent when carbon dioxide is used as the inert

(2) 9.3 percent when nitrogen is used as the inert

4.4.4* Type 4 machinery shall be permitted to be operated without inert gas protection if the following requirements are met:

(1) Manually operated valves shall be installed at each machine for control of feed and air lines.

(2)* The equipment shall be under supervision during operation and shall be shut down for detailed inspection and any necessary cleaning when abnormalities in operation indicate the possibility of fire within the machine.

(3) All valves shall be closed before opening the machine.

4.5 Conveyors and Collectors.

4.5.1 Only conveyors or spouts with positive seals, such as star feed rotary valves or screw conveyors with some flights removed, shall be permitted to pass through a fire partition separating crushing or pulverizing rooms from adjacent spaces.

4.5.2 The chokes or seals shall be located so as to prevent flame propagation through the partition.

4.5.3 Conveyors used to feed or discharge sulfur to or from grinding machinery shall be in dusttight housings.

4.5.4 Nonferrous buckets or bucket elevators shall be used where they are housed in ferrous casings.

4.5.5 Ferrous buckets or bucket elevators shall be permitted to be used with ferrous casings, provided that steam shall be blown into the elevator boot while the elevator is in operation or that an inert gas system meeting the requirements of 4.4.3 shall be used.

4.5.6 Unless the conveying system is inerted in accordance with 4.2.7(1), pneumatic conveying of sulfur shall not be permitted.

4.5.7 Each pulverizer shall have a separate and self-contained system.

4.5.8 Dust Collectors.

4.5.8.1 General.

4.5.8.1.1 Location.

4.5.8.1.1.1 Where an explosion hazard exists, dust collectors shall be located outside of buildings.

4.5.8.1.1.2* The requirement of 4.5.8.1.1.1 shall not apply to the following:

(1) Dust collectors that are protected in accordance with 4.2.7(1), (3), or (4).

(2) Dust collectors 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) The requirements of 4.5.8.1.1.1 shall not be required provided that the volume of the dust collector is less than 8 ft^3 (0.2 m^3).

4.5.8.1.2 Where both an explosion hazard and a fire hazard exist in a dust collector, provisions for protection of each type of hazard shall be provided.

4.5.8.1.3 Protection.

4.5.8.1.3.1 Dust collectors shall be protected in accordance with 4.2.7.

4.5.8.1.3.2 For dust collectors 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.

4.5.8.1.4 Manifolding of Dust Collection.

4.5.8.1.4.1 Manifolding of dust collection ducts to dust collectors shall not be permitted.

4.5.8.1.4.2 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.

4.5.8.1.4.3 Dust collection ducts from nonassociated pieces of equipment shall be permitted to be manifolded provided that each of the ducts is equipped with an isolation device prior to manifolding in accordance with 4.2.8.

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

4.5.8.1.5* Isolation devices shall be provided for dust collectors in accordance with 4.2.8.

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

4.5.8.1.7 Exhaust Conveying Gas.

4.5.8.1.7.1 Exhaust conveying gas from the final dust collector shall be discharged outside to a restricted area and away from air intakes.

4.5.8.1.7.2 Conveying gas from dust collectors shall be permitted to be recirculated within enclosed equipment systems.

4.5.8.2 Construction.

4.5.8.2.1 Noncombustible Material.

4.5.8.2.1.1 Dust collectors shall be constructed of noncombustible materials.

4.5.8.2.1.2 Filter media, when used, shall be permitted to be constructed of combustible material.

4.5.8.2.2 Maximum Material Flow.

4.5.8.2.2.1 Dust collectors shall be constructed so as to minimize internal ledges or other points of dust accumulation.

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

4.5.8.2.3 Access Doors.

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

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

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

4.5.8.2.3.4 Access doors shall be bonded and grounded.

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

4.6 Prevention of Ignition.

4.6.1 Foreign Materials.

4.6.1.1 Means shall be provided to prevent foreign materials from entering the system when such foreign materials present an ignition hazard.

4.6.1.2 Floor sweepings shall not be returned to any machine.

4.6.1.3* Foreign materials, such as tramp metal, that are capable of igniting sulfur 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) Inerted gas separators

(3) Grates or other separation devices

4.6.2 All machinery shall be installed and maintained in such a manner that the possibility of frictional sparks is minimized.

4.6.3 Interlocking controls shall be installed to stop the dust feed if the pulverizer stops or if the fans or blowers stop for any reason.

4.6.4* All machinery, conveyors, housings, and collectors shall be thoroughly bonded and grounded with a resistance of less than 1.0×10^6 ohms to ground to prevent the accumulation of static electricity.

4.6.5 Open Flames and Sparks. The requirements of 4.6.5.1 through 4.6.5.3 shall be applied retroactively.

4.6.5.1 Smoking shall be permitted only in designated areas.

4.6.5.2 Activities involving open flames, such as cutting or welding, heat, or hand or power tools, shall be permitted to be made only after all operations have ceased and all sulfur has been removed from the vicinity, protected in tight noncombustible containers, or sufficiently wet with water to prevent ignition.

4.6.5.3 Activities described in 4.6.5.2 shall be controlled by a hot work permit system in accordance with the requirements of NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

4.6.5.4 Heating shall be by indirect means.

4.6.5.5 Unprotected hot surfaces, such as steam lines, that can attain temperatures high enough to melt and ignite sulfur dust shall not be exposed in enclosures housing sulfur processing equipment.

4.6.6* **Propellant-Operated Tools.**

4.6.6.1 Propellant-operated tools shall not be used where combustible dust or dust clouds are present.

4.6.6.2 When the use of such tools becomes necessary, all dust-producing machinery in the area shall be shut down; all equipment, floors, and walls shall be cleaned thoroughly; and all accumulations of dust shall be removed.

4.6.6.3 After such work has been completed, a check shall be made to ensure that no cartridges or charges have been left on the premises where they could enter equipment or be accidentally discharged after operation of the dust-producing or dust-handling machinery is resumed.

4.6.6.4 Use of propellant-operated tools shall be controlled by a hot work permit system in accordance with the requirements of NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

4.7* Intermediate Bulk Containers for Solid Sulfur.

4.7.1 The requirements of 4.7.2 through 4.7.4 shall be applied retroactively.

4.7.2* Dispensing solid sulfur from intermediate bulk containers shall only be performed 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 with a resistance less than 1 megohm to ground.

(2)* 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.

(3)* 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.

(4)* Type A FIBC, Type B FIBC, or insulating RIBCs shall not be permitted to be used for solid sulfur applications, processes, or operations unless a documented risk evaluation assessing the electrostatic hazards, including the potential presence of hydrogen sulfide, is acceptable to the authority having jurisdiction.

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

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

4.8 Fire Fighting.

4.8.1* Fog nozzles shall be used when fighting fires in finely divided sulfur.

4.8.2* Steam and inert gases shall be permitted to be used as extinguishing agents for tightly closed containers provided that the sulfur dust is not disturbed.

4.8.3 In all cases, it shall be made certain that the fire is completely extinguished before disturbing the dust and that the sulfur has cooled sufficiently to prevent reignition.

4.8.4* When grinding or other processing equipment is opened for cleaning following an ignition, the feed, discharge, and other openings shall first be closed by suitable metal valves or gates.

4.8.5* Respiratory Protection.

4.8.5.1 At least two self-contained breathing apparatus shall be made available for use in case of sulfur fires.

4.8.5.2 All respiratory equipment shall be inspected at regular intervals and kept in working order at all times.

Chapter 5 Handling of Liquid Sulfur at Normal Handling Temperatures

5.1* General.

This chapter shall apply to the handling of liquid sulfur in the temperature range of 246°F to 309°F (119°C to 154°C).

5.2 Detection of Unsafe Conditions.

5.2.1* Devices for measuring the concentration of combustible gas in the atmosphere over liquid sulfur shall be designed for operation in atmospheres containing hydrogen sulfide.

5.2.2 Instruments used for detecting explosive atmospheres shall be capable of measuring the lower explosive limit of hydrogen sulfide, since it is the primary gas evolved from sulfur that can contribute to an explosive atmosphere.

5.2.3 Operations shall be discontinued whenever instruments show a combustible gas concentration of 35 percent or more of the lower explosive limit in the gas space of liquid sulfur containers.

5.2.4 Operations shall not be resumed until the instruments indicate a concentration of 15 percent or less of the lower explosive limit.

5.3 Equipment Design.

5.3.1 Liquid sulfur storage tanks shall be designed with fill lines that extend to near the tank bottom so that the incoming sulfur enters the tank below the surface of the sulfur in the tank, thereby minimizing agitation and release of hydrogen sulfide.

5.3.2 Vent Systems.

5.3.2.1 Covered storage tanks shall be provided with heated vent systems to provide natural venting of hydrogen sulfide.

5.3.2.2 Vent systems shall be maintained at a temperature above the melting temperature of sulfur.

5.3.3* Bonding and Grounding.

5.3.3.1 Sulfur lines and storage tanks shall be bonded and grounded with a resistance of less than 1.0×10^6 ohms to ground to prevent accumulation of static electricity.

5.3.3.2 Grounding connections shall be provided for the bonding of liquid sulfur tanks and tank cars being loaded or unloaded.

5.3.4* In pits or sections of tanks used for melting sulfur, and in liquid storage tanks that are regularly emptied, cooled, and exposed to air (moisture), the sulfur level shall be maintained above the heating coils.

5.3.5* All electrical wiring and equipment installed in areas handling liquid sulfur shall meet the requirements of Article 501 of NFPA 70, *National Electrical Code*.

5.4 Open Flames and Sparks.

The requirements of 5.4.1 through 5.4.3 shall be applied retroactively.

5.4.1 Smoking shall be permitted only in designated areas.

5.4.2 Activities involving open flames, such as cutting or welding, heat, or hand or power tools, shall be permitted to be made only after all operations have ceased and all sulfur has been removed from the vicinity, protected in tight noncombustible containers, or sufficiently wet with water to prevent ignition.

5.4.3 Activities described in 5.4.2 shall be controlled by a hot work permit system in accordance with the requirements of NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

5.5 Fire Fighting.

5.5.1 Protection for covered liquid sulfur storage tanks, pits, and trenches shall be by one of the following means:

(1) Inert gas system in accordance with NFPA 69, *Standard on Explosion Prevention Systems*

(2)* Steam extinguishing system capable of delivering a minimum of 2.5 lb/min (1.13 kg/min) of steam per 100 ft^3 (2.83 m^3) of volume

(3) Rapid sealing of the enclosure to exclude air

5.5.2* Where a fixed inerting system is used, thin corrosion-resistant rupture discs shall be placed over the inerting nozzles so that sulfur cannot condense within the nozzle.

5.5.3 Water Extinguishing Precautions.

5.5.3.1 Liquid sulfur stored in open containers shall be permitted to be extinguished with a fine water spray.

5.5.3.2 Use of high-pressure hose streams shall be avoided.

5.5.3.3 The quantity of water used shall be kept to a minimum.

5.5.4 Dry Chemical Extinguishers. Where sulfur is being heated by a combustible heat transfer fluid, dry chemical extinguishers complying with NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, shall be provided.

Chapter 6 Handling of Liquid Sulfur and Sulfur Vapor at Temperatures above 309°F (154°C)

6.1 General.

6.1.1 This chapter shall apply to liquid sulfur and its vapors when heated in closed containers to temperatures above 309°F (154°C).

6.1.2 The requirements of Chapter 5 shall apply.

6.2 Operating Precautions and Equipment Design.

6.2.1 Equipment shall be designed to be closed as tightly as possible to prevent escape of vapor and to exclude air from the system during operation.

6.2.2 Deflagration Venting.

6.2.2.1* Process equipment shall be provided with deflagration venting.

6.2.2.2 Where vent ducts are required, the vent pipes or ducts shall be heated to prevent condensation of sulfur vapor.

6.2.3 An adequate supply of a suitable inerting agent such as steam shall be available at all times for blanketing and purging equipment.

6.2.4 All buildings or enclosures for such processes shall comply with 4.2.1.1, 4.2.1.2, and 4.2.1.5 through 4.2.1.9.

6.2.5 Where sulfur is vaporized and subsequently condensed to sulfur dust, handling of the finely divided sulfur from the process shall comply with the requirements of Chapter 4.

Chapter 7 Fugitive Dust Control and Housekeeping

7.1 Fugitive Dust Control.

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

7.1.2 The dust shall be conveyed to dust collectors.

7.2 Housekeeping.

The requirements of 7.2.1 through 7.2.3 shall be applied retroactively.

7.2.1* General.

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

7.2.1.2* 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.

7.2.2* Cleaning.

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

7.2.2.2* 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.

7.2.3 Vacuum Cleaners.

7.2.3.1 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 4.5.8.

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

Chapter 8 Training and Procedures

8.1 Employee Training.

The requirements of 8.1.1 through 8.1.3 shall be applied retroactively.

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

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

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

8.1.4 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 start-up and shutdown, and response to upset conditions

(5) The necessity for related fire and explosion protection systems to function as designed and installed

(6) Equipment maintenance requirements and practices

(7) Housekeeping requirements

(8)* Emergency response plans

8.1.5 The employer shall certify annually that the training and review required by 8.1.1 through 8.1.4 have been completed.

Chapter 9 Inspection and Maintenance

9.1 General.

The requirements of 9.1.1 through 9.1.3 shall be applied retroactively.

9.1.1 An inspection, testing, and maintenance program shall be developed and implemented to ensure that the fire and explosion protection systems and related process controls and equipment perform as designed.

9.1.2 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

9.1.3 Records shall be kept of maintenance and repairs performed.

9.2 Specific Equipment Maintenance.

9.2.1 Maintenance of Material-Feeding Devices.

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

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

9.2.2 Maintenance of Fan and Blowers.

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

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

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

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

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

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

9.2.3 Maintenance of Dust Collectors.

9.2.3.1 Means to Dislodge.

9.2.3.1.1 Dust collectors that are equipped with a means to dislodge particulate from the surface of filter media shall be inspected periodically as recommended in the manufacturers' instructions for signs of wear, friction, or clogging.

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

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

9.2.4 Maintenance of Fire and Explosion Protection Systems.

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

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

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

9.2.4.4 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.1.1.1 Sulfur differs from most other combustible dusts found in industry in that it has relatively low melting and ignition points. Depending on purity, sulfur melts at or slightly below 246°F (119°C). The ignition temperature of a dust cloud is 374°F (190°C); the ignition temperature of a dust layer is 428°F (220°C). Dilution of sulfur with inert solids is not effective in raising the ignition temperature. Sulfur is handled and processed in the liquid and vapor states in some cases. The liquid is highly combustible, and the vapor is explosive when mixed with air in the proper proportions.

The finely divided sulfur produced during crushing and pulverizing is the most hazardous from an explosion standpoint. Also, mixtures containing finely divided elemental sulfur can be just as hazardous if the sulfur is present in sufficient quantity. Some explosion and fire hazards also accompany the handling and processing of sulfur in bulk in coarse sizes due to the fine dust present.

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 representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.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 Dust Explosion Hazard. A relatively small initial dust deflagration can disturb and suspend in air dust that has been allowed to accumulate on the flat surfaces of a building or equipment. This dust cloud provides fuel for the secondary deflagration, which can cause damage. Reducing significant additional dust accumulations is therefore a major factor in reducing the hazard in areas where a dust hazard can exist.

Using a bulk density of 75 lb/ft^3 (1200 kg/m^3) and an assumed concentration of 0.35 oz/ft^3 (350 g/m^3), it has been calculated that a dust layer averaging $\frac{1}{32}$ 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 $\frac{1}{32}$ 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 $\frac{1}{32}$ in. (0.8 mm) layer of dust on the floor is obviously hazardous and should be cleaned. This same 100 ft^2 (9.3 m^2) area in a 2025 ft^2 (188 m^2) building is also a moderate hazard. This area represents about 5 percent of a floor area and is about as much coverage as should be allowed in any plant. To gain proper perspective, the overhead beams and ledges should also be considered. Rough calculations show that the available surface area of the bar joist is about 5 percent of the floor area. For steel beams, the equivalent surface area can be as high as 10 percent.

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

(1) Dust layers $\frac{1}{32}$ in. (0.8 mm) thick can be sufficient to warrant immediate cleaning of the area [$\frac{1}{32}$ 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.

Guidelines (1) through (7) serve to establish a cleaning frequency.

A.3.3.3.2 Rigid Intermediate Bulk Container (RIBC). These are often called composite IBCs, which is the term used by U.S. Department of Transportation (DOT) to describe them. The term *rigid nonmetallic intermediate bulk container* also denotes an all-plastic single-wall IBC that could or could not have a separate plastic base and for which the containment vessel also serves as the support structure.[**654,** 2006]

A.3.3.5 Sulfur Dust. The Committee is aware of data contained in R. K. Eckhoff's *Dust Explosions in the Process Industries*, 3rd edition, Table A1, p. 698, which reported positive explosion test results of a sulfur dust cloud with a median particle size of 120 microns as being explosible.

A.4.1.2(4) The grinding in Type 4 machines is accomplished by attrition of the particles on themselves. Power for moving the particles is furnished by compressed air or other fluid suitable to the material being pulverized.

A.4.2.1.3 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 or similar structural shapes can be boxed with concrete or other noncombustible material to eliminate surfaces for dust accumulation. Surfaces should be as smooth as possible to minimize dust accumulations and to facilitate cleaning.

A.4.2.1.10 The use of load-bearing walls should be avoided to prevent structural collapse should an explosion occur.

A.4.2.2.2 It is not the intent of this requirement to prohibit interim storage of bags, drums, or filled containers.

A.4.2.3.2 The grinding space should preferably be detached. Exterior walls could require explosion venting. Steel frame construction, with light, nonbearing exterior walls and light roof, is preferable.

A.4.2.4.2 It is recommended that an emergency escapeway for personnel be provided independently.

A.4.2.5 See NFPA 68, *Guide for Venting of Deflagrations*.

A.4.2.7(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 of the material being conveyed, particles can be abraded and broken, exposing unoxidized metal (virgin metal) to the transport gas. When this metal is finally exposed to oxygen containing air, the rapid oxidation of this virgin metal 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.4.2.7(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.4.2.8 Methods of explosion protection using containment, venting, and suppression protect the specific process equipment on which they are installed. Flame fronts from a deflagration can propagate through connecting ductwork to other unprotected process equipment and to the building from outside process equipment. Figure A.4.2.8 shows an example of how this propagation might occur. Isolation techniques as shown in Figure A.4.2.8.2(3) through Figure A.4.2.8.2(5) can be used to prevent the propagation of the deflagration by arresting the flame front.

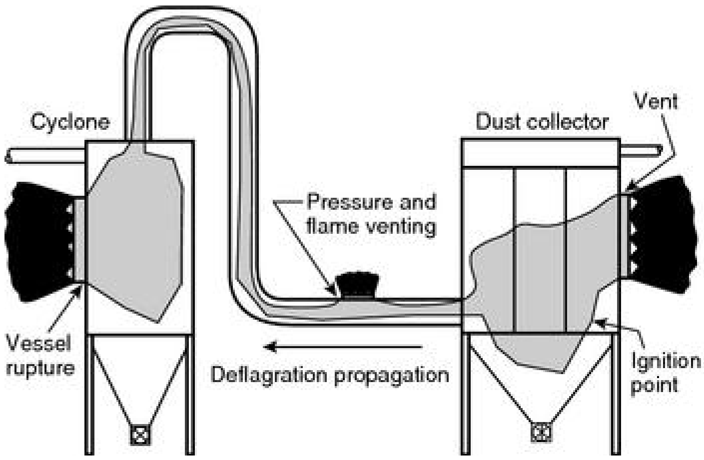

FIGURE A.4.2.8 An Example of Deflagration Propagation Without Isolation. [654: Figure E.1]

Both the direction and extent of potential deflagration propagation must 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 that are many times greater than the initial deflagration volume.

The dynamics of a dust explosion are such that unburned dust is pushed ahead of the flame front by the expanding products of combustion. This 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 force pushing the dust away from the point of initiation (which, under vented conditions, might be in the range of a few psi) can easily overcome the force of normal system flow (which typically might 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.

The conveyance of the flame front via both the in-feed and outflow ducts should be evaluated. In most cases, this movement of dust and propagating flame front will commute 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 the property damage. However, in other cases, the transit of a deflagration flame front does result in substantial increases in the severity of an event.

In the case of several pieces of equipment connected together 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 will prevent overpressure damage to that vessel. If the concentration within the connecting ductwork is below the minimum explosible concentration (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.

If the concentration within a connecting duct is above the MEC prior to the deflagration, then the propagation through that duct will result in an accelerating flame front. Without explosion venting on the ductwork, this accelerating flame front will result in a significant prepressurization of the equipment at the other end of the duct and in a very powerful jet flame ignition of a dust deflagration within 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 this case, the explosion propagation results in a significant increase in the 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.

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 of the connected silos could cause ignition of the material stored in all of 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 previous example of a connecting duct having a concentration above MEC prior to deflagration, explosion isolation would be warranted in this case.

A.4.2.8.2(1) Figure A.4.2.8.2(1) illustrates two different designs of chokes.

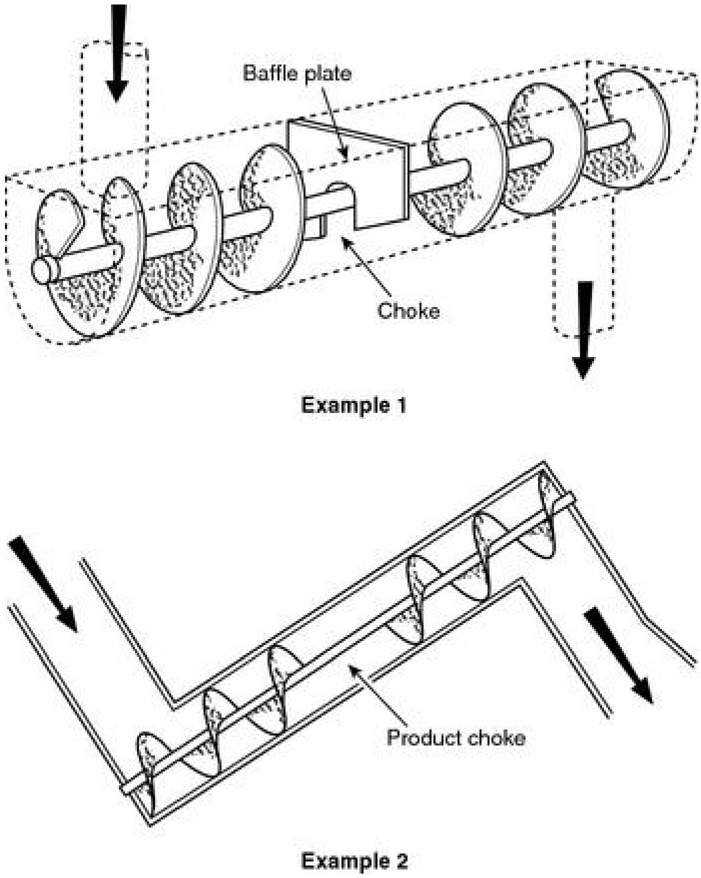

FIGURE A.4.2.8.2(1) Screw Conveyor Chokes. [654:Figure A.7.1.4.2(1)]

A.4.2.8.2(2) When rotary valves are installed in both the inlet and outlet of equipment, care should be taken to ensure that the rotary valve on the inlet is stopped before the unit becomes overfilled. See Figure A.4.2.8.2(2) for an example of rotary valves.

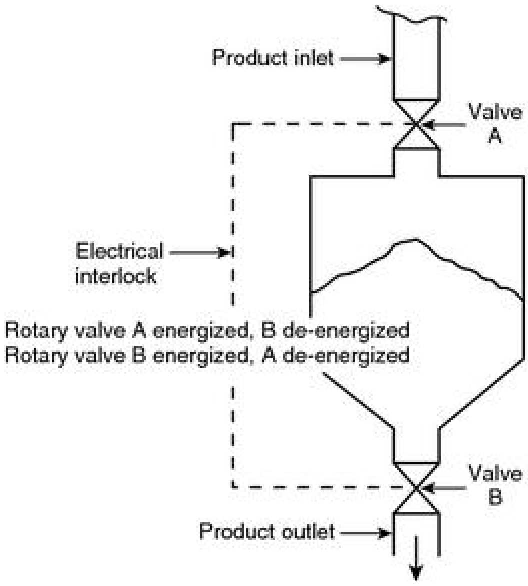

FIGURE A.4.2.8.2(2) Rotary Valves. [654: Figure A.7.1.4.2(2)]

A.4.2.8.2(3) Figure A.4.2.8.2(3) illustrates one example of deflagration propagation using mechanical isolation.

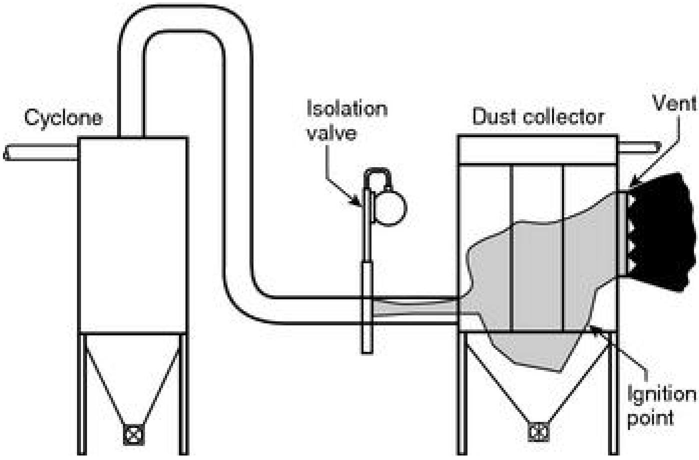

FIGURE A.4.2.8.2(3) Deflagration Propagation Using Mechanical Isolation. [654: Figure A.7.1.4.2(3)]

A.4.2.8.2(4) Figure A.4.2.8.2(4) illustrates one example of deflagration propagation using flame front diversion.

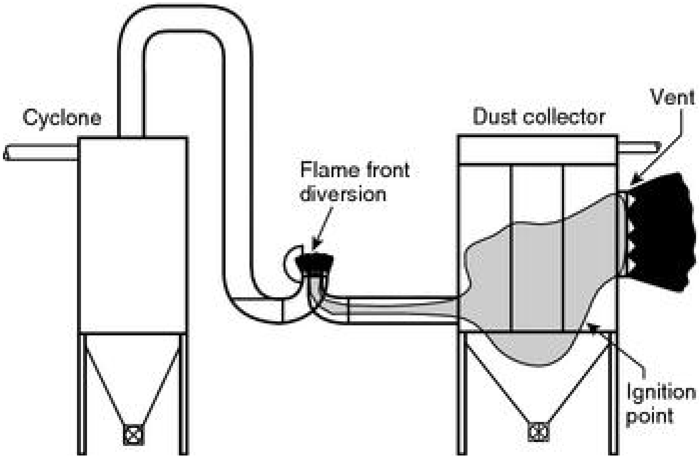

FIGURE A.4.2.8.2(4) Deflagration Propagation Using Flame Front Diversion. [654: Figure A.7.1.4.2(4)]

A.4.2.8.2(5) Figure A.4.2.8.2(5) illustrates one example of deflagration propagation using chemical isolation.

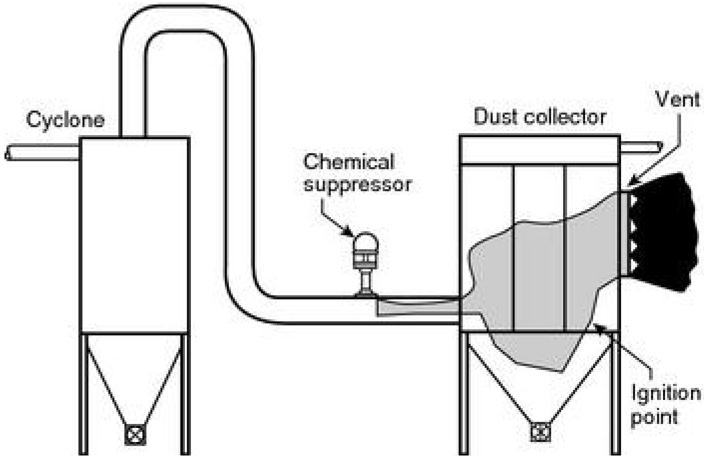

FIGURE A.4.2.8.2(5) Deflagration Propagation Using Chemical Isolation. [654: A.7.1.4.2(5)]

A.4.2.8.4 A means to determine protection requirements should be based on a risk evaluation, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. See the American Institute of Chemical Engineers — Center for Chemical Process Safety, *Guidelines for Hazard Evaluation Procedures*.

A.4.3 Although sulfur is not now included in atmospheres classified as Class II, Group G, it has been the experience of the sulfur industry that such equipment can be suitable. However, consideration should be given to the melting point of sulfur, 233°F to 246°F (112°C to 119°C), in the selection of heat-producing electrical equipment.

A.4.3.2 Refer to NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*. Table A.4.3.2 provides guidance for area electrical classification.

Table A.4.3.2 Guidance for Area Electrical Clas

Depth of Dust Accumulation (in.)	Frequency	Housekeeping Re
Negligible[a]	N/A	N/A
Negligible to < 1/32[b]	Infrequent[c]	Cleanup during s
Negligible to < 1/32[b]	Continuous/frequent[d]	Clean as necessary to ma accumulation belc
1/32 to 1/8	Infrequent[c]	Cleanup during s
1/32 to 1/8	Continuous/frequent[d]	Clean as necessary to ma accumulation bel
>1/8	Infrequent[c]	Immediately shut do
>1/8	Continuous/frequent[d]	Clean at frequency a minimize accun

Table A.4.3.2 Guidance for Area Electrical Clas

Depth of Dust Accumulation (in.)	Frequency	Housekeeping Re

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 sta 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

[f] For example, National Electrical Manufacturers Association (NEMA) 12 or better. Note: Ordinary equipmen significantly sealed against dust penetration by the use of silicone-type caulking. This can be considered in are accumulate over a long period of time.

[g] Guidance to be applied for existing facilities. For new facilities, it is recommended that the electrical classifi

[**654:** Table A.6.6.2]

A.4.4.2(1) See Figure A.4.2.8.2(1) for an illustration of two different designs of chokes.

A.4.4.3.3 Auxiliary instrumentation should be provided for sampling and recording the quality of the inert atmosphere in other parts of the system.

A.4.4.4 The large volumes and high velocities of air and the compactness of the Type 4 unit make inerting usually impractical.

A.4.4.4(2) Flooding with inert gas or steam, combined with delayed opening to permit smothering of any residual fire, is recommended.

A.4.5.8.1.1.2 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 will 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.4.5.8.1.5 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.4.5.8.2.3.5 See NFPA 68, *Guide for Venting of Deflagrations*.

A.4.6.1.3 It should be recognized that magnetic separators will not remove nonferrous tramp material, including stones, brick, and concrete. Every care, using other means, should be taken to ensure excluding such materials from the grinding system.

A.4.6.4 See NFPA 77, *Recommended Practice on Static Electricity*, for information on the subject.

A.4.6.6 Propellant-operated tools include all of the following:

(1) Cartridge operated

(2) Powder operated

(3) Tools using combustible gas as the propellant

A.4.7 For further information regarding the hazards and uses of flexible and rigid intermediate bulk containers see NFPA 77, *Recommended Practice on Static Electricity*, Section 9.1, and "Avoiding Static Ignition Hazards in Chemical Operations," Britton, CCPS, New York, NY, 1999, pp. 199–204.

A.4.7.2 Unless intentionally removed by the process, sulfur typically contains adsorbed hydrogen sulfide. Dispensing generates static charge, which can ignite not only the combustible dust atmosphere but also the hydrogen sulfide. Minimum ignition energy (MIE) of less than 1 mJ has been reported for particulate sulfur, while MIE of 0.068 mJ has been reported for hydrogen sulfide. MIEs are measured in accordance with ASTM E 2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.

A.4.7.2(2) Due to the particularly low minimum ignition energy (MIE) of hydrogen sulfide, the suitability of specific manufacturers' Type C FIBCs in the presence of hydrogen sulfide atmospheres should be determined. Failure to provide grounding for a Type C FIBC can create a potential static discharge hazard greater than using Type A or Type B FIBCs.

A.4.7.2(3) Due to the particularly low MIE of hydrogen sulfide, the suitability of specific manufacturers' Type D FIBCs in the presence of hydrogen sulfide atmospheres should be determined.

A.4.7.2(4) Examples of situations where Type A or Type B FIBCs could be appropriate are as follows:

(1) Atmospheres both inside and outside the FIBC are kept outside the combustible range.

(2) Emptying velocities are slow enough to prevent electrostatic charge generation and accumulation.

(3) MIEs are sufficiently high to preclude ignition by electrostatic discharges.

A Type B FIBC should only be used for dispensing into dust atmospheres where the minimum ignition energy is greater than 3 mJ and no flammable vapor or gas is present.

A.4.7.3 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 flammable atmospheres and has been used in FIBCs is documented in Ebadat and Mulligan, "Testing the Suitability of FIBCs for Use in Flammable Atmospheres," *Process Safety Progress,* Vol. 15, No. 3.

A.4.8.1 Straight streams from hoses or extinguishers should not be used, as a cloud of dust can be raised that explodes on contact with the fire.

A.4.8.2 If a container is tightly closed and the volume of oxygen enclosed is not too large, a fire will be smothered by the sulfur dioxide formed. When steam is used for fire suppression in enclosed equipment, the rate of application should be at least 2.5 lb/min/100 ft^3 (1.13 kg/min/2.83 m^3).

A.4.8.4 A period of at least 15 minutes should elapse between closing the valves or gates and opening the equipment to smother any residual fire in the equipment. As an added precaution, the equipment should be flooded with inert gas or steam, if available, prior to opening.

A.4.8.5 Gas masks approved for acid gases will not provide adequate protection in a serious sulfur fire. Self-contained breathing apparatus of the pressure demand type should be used.

A.5.1 The normal handling temperature of liquid sulfur is 250°F to 309°F (121°C to 154°C), which is slightly above the melting point of 246°F (119°C). At the melting point sulfur is a transparent, mobile liquid. As the temperature of the liquid is raised, it darkens, becoming deep orange in hue. Up to about 320°F (160°C) the viscosity drops with rising temperature. Above this point the viscosity increases with rising temperature. At 370°F (188°C) the viscosity reaches a tremendously high maximum that practically prevents it from flowing and the liquid is so intensely colored as to be nearly opaque. Above 370°F (188°C) it again acts in a more normal fashion with its viscosity falling somewhat as the temperature continues to rise.

At the normal handling temperature of liquid sulfur [250°F to 309°F (121°C to 154°C)] the vapor concentration above the pure sulfur, free of hydrocarbons or hydrogen sulfide, is too low to form a flammable mixture in air. While the flash point of liquid sulfur varies with purity, it is always higher than the normal handling temperature. For pure sulfur, the flash point can be as low as 370°F (188°C) and for relatively impure crude sulfur, the flash point can be as low as 334°F (168°C).

The relative low ignition temperature of sulfur and the possible presence of hydrogen sulfide are the primary fire and explosion hazards of liquid sulfur. Impure sulfur (sometimes referred to as “dark sulfur”) contains hydrocarbons, which react slowly with the liquid sulfur to form hydrogen sulfide. Recovered sulfur, such as that produced from petroleum gas streams containing the hydrogen sulfide using the Claus Process, often contain dissolved hydrogen sulfide, which will be liberated slowly from a quiescent body of liquid sulfur. Agitation of such liquid sulfur will cause rapid evolution of hydrogen sulfide, which can create a flammable atmosphere within the storage tank. In the temperature range at which the liquid sulfur is normally handled, the lower flammable limit for hydrogen sulfide is at about 3.4 percent compared to 4.3 percent at room temperature.

Pure sulfur will not generate a flammable atmosphere in the normal temperature range of the liquid. Transfer of liquid sulfur using air pressure should be avoided. If air pressure is applied to the vapor space of an enclosure containing molten sulfur with high concentrations of hydrogen sulfide, there is a danger that the hydrogen sulfide/air mixture will become flammable. Transfer by pressure should be restricted to using an inert gas. Use of pumps would be the preferred transfer method.

Because impurities can cause generation of H_2S or pyrophoric iron sulfides, testing a representative sample of incoming batches for carbon content and hydrogen sulfide should be performed. These impurities should be kept to a minimum.

A.5.2.1 The sensing elements of some explosimeters are not designed for and are adversely affected by hydrogen sulfide–containing atmospheres.

A.5.3.3 See NFPA 77, *Recommended Practice on Static Electricity*, for information on the subject.

A.5.3.4 Pyrophoric iron sulfide compounds can form from impurities in the sulfur. When heating coils are exposed to air, ignition can occur.

A.5.3.5 Due to the potential for release of dissolved hydrogen sulfide, molten sulfur handling systems require a Class I, Group C, classification for confined areas.

A.5.5.1(2) The steam should preferably be introduced near the surface of the molten sulfur. See NFPA 86, *Standard for Ovens and Furnaces*, Section F.3.

A.5.5.2 Sulfur flour can cause a dust explosion if it is ejected from the nozzles ahead of the inerting agent.

A.6.2.2.1 See NFPA 68, *Guide for Venting of Deflagrations*.

A.7.2.1 See A.3.3.2, Dust Explosion Hazard.

A.7.2.1.2 It is recommended that the interior of crushing, pulverizing, and packaging rooms or buildings be painted a color that contrasts with the color of the dust.

A.7.2.2 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.7.2.2.2 Push brooms should have natural bristles.

A.8.1.4(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 effect 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

Simulated emergency drills should be performed annually by plant personnel. Malfunctions of the process should be simulated and emergency actions undertaken. Disaster drills that simulate a major 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.9.1.2(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.9.2.2.4 Periodic cleaning of components is especially important if the blower or fan is exposed to heated air.

A.9.2.2.5 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.9.2.4.3 For information on maintenance of deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

Annex B Informational References

B.1 Referenced Publications.

The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

B.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

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

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

NFPA 77, *Recommended Practice on Static Electricity*, 2007 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 2007 edition.

NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 2004 edition.

B.1.2 Other Publications.

B.1.2.1 AIChE Publications. American Institute of Chemical Engineers, Three Park Avenue, New York, NY 10016-5991.

Guidelines for Hazard Evaluation Procedures.

Guidelines for Safe Automation of Chemical Processes.

B.1.2.2 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM E 2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air,* 2003.

B.1.2.3 FMGR Publications. FM Global Research, FM Global, 1301 Atwood Avenue, P.O. Box 7500, Johnston, RI 02919.

FM Data Sheet, 7-76, Operations and Maintenance.

B.1.2.4 Other Publications.

Britton, L., *Avoiding Static Ignition Hazards in Chemical Operations,* CCPS, New York, NY, 1999, pp. 199–204.

Ebadat and Mulligan, "Testing the Suitability of FIBCs for Use in Flammable Atmospheres," *Process Safety Progress,* Vol. 15, No. 3, 1996.

Eckhoff, R. K., *Dust Explosions in the Process Industries,* Oxford, UK: Butterworth-Heinemann Ltd., 3rd edition, 2003.

B.2 Informational References.

The following documents or portions thereof are listed here as informational resources only. They are not a part of the requirements of this document.

B.2.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 51, *Standard for the Design and Installation of Oxygen–Fuel Gas Systems for Welding, Cutting, and Allied Processes*, 2002 edition.

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

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2006 edition.

B.2.2 Additional Publications.

Furno, Aldo L., G. H. Martindill, and M. G. Zebetakis: "Gas Explosion Hazards Associated with the Bulk Storage of Molten Sulfur," U.S. Department of the Interior, Bureau of Mines RI 6185 (1963).

Handling and Storage of Solid Sulfur, National Safety Council, Data Sheet I-612, revised 1991.

Handling Liquid Sulfur, National Safety Council, Data Sheet 592, revised 1993.

Lagas, Jan A., et al., "Understanding the Formation of and Handling of H_2S and SO_2 Emissions from Liquid Sulphur During Storage and Transportation."

Schicho, C. M., W. A. Watson, K. R. Clem, and D. Hartley: "A New Safer Method of Sulfur

Degassing," *Chemical Engineering Progress,* October 1985, pp. 42–44.

Wiewiorwski, T. K., and F. J. Touro: "The Sulfur-Hydrogen Sulfide System," *Journal of Physical Chemistry,* vol. 70, pp. 234–239 (January No. 1) (1966).

B.3 References for Extracts in Informational Sections.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2006 edition.

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