NFPA®

654

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

2020

NFPA®

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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

2020 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, released by the Correlating Committee on Combustible Dusts, and acted on by NFPA at its June Association Technical Meeting held June 17–20, 2019, in San Antonio, TX. It was issued by the Standards Council on August 5, 2019, with an effective date of August 25, 2019, and supersedes all previous editions.

This edition of NFPA 654 was approved as an American National Standard on August 25, 2019.

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 edition, 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In 1994, the standard was revised to improve its usability, adoptability, and enforceability; to update outdated terminology; and to add the NFPA language for equivalency and retroactivity.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 incorporated a complete revision, which introduced a performance-based approach for protecting combustible particulate solids processing facilities. This approach enabled users of the standard to follow the traditional prescriptive method or, for unique situations, allowed the option of a performance-based design. Other changes included updating the standard to the current *Manual of Style for NFPA Technical Committee Documents* format.

The 2013 edition incorporated updates to definitions to coordinate with extracted text from the source documents in accordance with the *Manual of Style for NFPA Technical Committee Documents*. The most important change was the inclusion of four methods to determine whether a dust fire or explosion hazardous condition exists in a facility. The methods include those based on mass accumulation and risk evaluation as well as the layer depth criterion, which was described in the 2006 edition. Each of the methods was viewed as equivalent in establishing that a hazardous condition exists for either fires or explosions, so the change offered options for users of the standard when determining this fundamental condition.

The standard included changes to the housekeeping requirements in two aspects. One involved the determination of a dust hazardous condition and prompts a cleaning frequency based on the nature of the dust layer or dust mass. The second change established a hierarchy for cleaning methods: vacuuming first, followed by sweeping or water wash and then, if still necessary, blowing with compressed air, but only under controlled conditions. It is clearly recognized from the incidents reported over the past decade or more that housekeeping has not been adequate in all instances, so establishing a strategy for cleaning frequency based on accumulated dust will improve the practice. In some instances, improper housekeeping has contributed to incidents, so creating a preferred sequence for cleaning methods will increase safety as well.

Safety management elements also were strengthened in the standard, including hazard analysis, management of change, training, emergency procedures, incident investigations, and contractor/subcontractor safety. Incident investigations indicated that one or more of these elements were reported as contributing factors to various incidents, so including them in the standard stressed their importance in the overall safety culture at a facility.

The 2017 edition included changes designed to begin the alignment of the standard with the newly issued NFPA 652, *Standard on the Fundamentals of Combustible Dust*. Definitions used in NFPA 654 were aligned with those in NFPA 652, and the objectives in Chapter 4 were updated. Although the requirement to perform a hazard analysis had been part of the standard since the 2006 edition, requirements to perform a dust hazard analysis (DHA) retroactively were added for those facilities constructed prior to the 2006 edition. The work to align NFPA 654 with NFPA 652 will continue in the next revision cycle.

The 2020 edition is a complete reorganization of the document. Many of the existing requirements were moved to align the document with NFPA 652, *Standard on the Fundamentals of Combustible Dust*, and any material previously extracted into NFPA 652 from NFPA 654 is now hosted in NFPA 652. Where requirements in the code are retroactive, statements were made to clearly indicate this to the user. New requirements for ultrafine particles (including nanopowders and nanoparticles) and additive manufacturing have been added to recognize unique hazards and developing technology, and requirements covering static, conductivity, and portable vacuum cleaners have been extracted from NFPA 652. The deadline for performing a dust hazard analysis (DHA) on existing processes and facility compartments is now specified to align with NFPA 652.

Correlating Committee on Combustible Dusts

Kevin Kreitman, *Chair*
Albany Fire Department, OR [E]

Chris Aiken, Cargill, Inc., MN [U]

Matthew J. Bujewski, MJB Risk Consulting, MO [SE]

John M. Cholin, J. M. Cholin Consultants Inc., NJ [SE]

Gregory F. Creswell, Cambridge-Lee Industries, PA [M]

Scott G. Davis, GexCon U.S., MD [SE]

Walter L. Frank, Frank Risk Solutions, Inc., DE [SE]

Robert C. Gombar, Baker Engineering & Risk Consultants, Inc., MD [U]
Rep. U.S. Beet Sugar Association

John A. LeBlanc, FM Global, MA [I]
Rep. FM Global

Arthur P. Mattos, Jr., TUV SUD America Inc./Global Risk Consultants, NC [SE]

Steve McAlister, Michelin North America, SC [U]

Jack E. Osborn, Airdusco, Inc., TN [M]

Jeffrey R. Roberts, AXA XL/Global Asset Protection Services, LLC, MS [I]

Bill Stevenson, CV Technology, Inc., FL [M]

Jérôme R. Taveau, Fike Corporation, MO [M]

Alternates

Christopher D. Headen, Cargill, Inc., MN [U]
(Alt. to Chris Aiken)

Jason Krbec, CV Technology, Inc., FL [M]
(Alt. to Bill Stevenson)

Adam Morrison, Fike Corporation, MO [M]
(Alt. to Jérôme R. Taveau)

Nonvoting

Mark W. Drake, Liberty Mutual, KS [I]
Rep. TC on Combustible Metals and Metal Dusts

William R. Hamilton, U.S. Department of Labor, DC [E]

Paul F. Hart, American International Group, Inc. (AIG), IL [I]
Rep. TC on Fundamentals of Combustible Dusts

Timothy J. Myers, Exponent, Inc., MA [SE]
Rep. TC on Agricultural Dusts

Jason P. Reason, Lewellyn Technology, IN [SE]
Rep. TC on Wood and Cellulosic Materials Processing

Mark L. Runyon, Marsh Risk Consulting, OR [I]
Rep. TC on Handling and Conveying of Dusts, Vapors, and Gases

Laura E. Moreno, NFPA Staff Liaison

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Committee Scope: This Committee shall have primary responsibility for documents on the hazard identification, prevention, control, and extinguishment of fires and explosions in the design, construction, installation, operation, and maintenance of facilities and systems used in manufacturing, processing, recycling, handling, conveying, or storing combustible particulate solids, combustible metals, or hybrid mixtures.

Technical Committee on Handling and Conveying of Dusts, Vapors, and Gases

Mark L. Runyon, *Chair*
Marsh Risk Consulting, OR [I]

Brice Chastain, Georgia-Pacific LLC, SC [U]
John M. Cholin, J. M. Cholin Consultants Inc., NJ [SE]
Ashok Ghose Dastidar, Fauske & Associates, LLC, IL [SE]
Burke Desautels, IEP Technologies/Hoerbiger, MA [M]
Tony DiLucido, Zurich Risk Engineering Services, PA [I]
Larry D. Floyd, BASF, AL [U]
Walter L. Frank, Frank Risk Solutions, Inc., DE [SE]
Stephen T. Greeson, HSB Professional Loss Control, TX [I]
Paul F. Hart, American International Group, Inc. (AIG), IL [I]
Mark L. Holcomb, Kimberly-Clark Corporation, WI [U]
Jerry J. Jennett, Georgia Gulf Sulfur Corporation, GA [U]
James F. Koch, Dow Corning Corporation, MI [U]
Rep. American Chemistry Council
Bruce McLelland, Fike Corporation, MO [M]
Jack E. Osborn, Airdusco, Inc., TN [M]
Philip J. Parsons, Baker Engineering & Risk Consultants, Inc., TX [SE]
Richard Pehrson, Pehrson Fire PC, MN [E]
Rep. International Fire Marshals Association
Jason P. Reason, Lewellyn Technology, IN [SE]
Ali Reza, Exponent, Inc., CA [SE]
James L. Roberts, Fluor Enterprises, Inc., SC [SE]
Samuel A. Rodgers, Honeywell, Inc., VA [U]
Andrew Ryerson, FM Global, MA [I]
Rep. FM Global
Thomas C. Scherpa, DuPont, NH [U]
Bill Stevenson, CV Technology, Inc., FL [M]
Jeffery W. Sutton, TUV SUD America Inc./Global Risk Consultants Corporation, MN [SE]
Robert D. Taylor, PRB Coal Users Group, IN [U]
Tony L. Thomas, Flamex, Inc., NC [M]
Erdem A. Ural, Loss Prevention Science & Technologies, Inc., MA [SE]

Alternates

Glenn W. Baldwin, Corning Corporation, WV [U]
(Alt. to James F. Koch)
Randal R. Davis, IEP Technologies/HOERBIGER, MA [M]
(Alt. to Burke Desautels)
John A. Donner, Dominion Energy, VA [U]
(Alt. to Robert D. Taylor)
Randall Dunlap, Georgia Gulf Sulfur Corporation, GA [U]
(Alt. to Jerry J. Jennett)
Eric Jandrain, Georgia-Pacific LLC, WI [U]
(Alt. to Brice Chastain)
James Karnesky, Exponent, Inc., CA [SE]
(Alt. to Ali Reza)
David C. Kirby, Baker Engineering & Risk Consultants, Inc., WV [SE]
(Alt. to Philip J. Parsons)
Jason Krbec, CV Technology, Inc., FL [M]
(Alt. to Bill Stevenson)
Robert D. Shafto, Zurich Insurance, MI [I]
(Alt. to Tony DiLucido)
Jérôme R. Taveau, Fike Corporation, MO [M]
(Alt. to Bruce McLelland)
Eric R. Winter, The DuPont Company, Inc., NJ [U]
(Alt. to Thomas C. Scherpa)

Nonvoting

William R. Hamilton, U.S. Department of Labor, DC [E]

Laura E. Moreno, NFPA Staff Liaison

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

Contents

NFPA 654

Standard for the

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

2020 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. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

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

Chapter 1 Administration

1.1* Scope.

1.1.1* This standard provides requirements for all phases of the manufacturing, processing, blending, conveying, repackaging, and handling of combustible dusts and particulate solids or hybrid mixtures, regardless of concentration or particle size, where the materials present a fire, a flash fire, or an explosion hazard.

N **1.1.2** This standard includes specific requirements for additive manufacturing.

1.1.3 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 necessary to manage safety to life and property from fire, flash fire, and explosion hazards involving combustible particulate solids, including hybrid mixtures, and to minimize the resulting damage from a fire or an 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 be used to supplement the requirements established by NFPA 652.

1.4.2 This standard shall not apply to the following:

(1) Storage or use of consumer quantities of such materials on the premises of residential or office occupancies
(2) Storage or use of commercially packaged materials at retail facilities
(3) Such materials displayed in original packaging in mercantile occupancies and intended for personal or household use or as building materials
(4) Warehousing of sealed containers of such materials when not associated with an operation that handles or generates combustible dust
(5) Such materials stored or used in farm buildings or similar occupancies for on-premises agricultural purposes

Δ **1.4.3** This standard shall not be required to apply to materials covered by the following documents, unless specifically referenced by the applicable document:

(1) NFPA 30B
(2) NFPA 33
(3) NFPA 61
(4) NFPA 85
(5) NFPA 120
(6) NFPA 400
(7) NFPA 484
(8) NFPA 495
(9) NFPA 655
(10) NFPA 664
(11) NFPA 1125

1.5 Conflicts.

1.5.1 Where a requirement specified in this industry-specific standard differs from a requirement specified in NFPA 652, the requirement in this standard shall be permitted to be used.

1.5.2 Where a requirement specified in this standard specifically prohibits a requirement specified in NFPA 652, the prohibition in this standard shall apply.

1.6* 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.

1.6.1 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.

1.6.2 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.

1.6.3 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.

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

1.7 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.

1.7.1 Technical documentation shall be made available to the authority having jurisdiction to demonstrate equivalency.

1.7.2 The authority having jurisdiction shall be permitted to require that the system, method, or device shall be approved for the intended purpose.

N **1.8 Units and Formulas.** Where extracted text contains values expressed in only one system of units, the values in the extracted text have been retained without conversion to preserve the values established by the responsible technical committee in the source document.

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.

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

NFPA 10, *Standard for Portable Fire Extinguishers,* 2018 edition.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2016 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2018 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 2018 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2019 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2019 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2017 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems,* 2019 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 2017 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2020 edition.

NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products,* 2019 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials,* 2018 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2019 edition.

NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities,* 2017 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2018 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 2019 edition.

NFPA 70®, National Electrical Code®, 2020 edition.

NFPA 72®, National Fire Alarm and Signaling Code®, 2019 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2019 edition.

NFPA 85, *Boiler and Combustion Systems Hazards Code,* 2019 edition.

NFPA 86, *Standard for Ovens and Furnaces,* 2019 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids,* 2015 edition.

NFPA *101®, Life Safety Code®,* 2018 edition.

NFPA 120, *Standard for Fire Prevention and Control in Coal Mines,* 2015 edition.

NFPA 220, *Standard on Types of Building Construction,* 2018 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls,* 2018 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies,* 2017 edition.

NFPA 400, *Hazardous Materials Code,* 2019 edition.

NFPA 484, *Standard for Combustible Metals,* 2019 edition.

NFPA 495, *Explosive Materials Code,* 2018 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations,* 2018 edition.

NFPA 652, *Standard on the Fundamentals of Combustible Dust,* 2019 edition.

NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions,* 2017 edition.

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities,* 2017 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2019 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 2020 edition.

NFPA 1125, *Code for the Manufacture of Model Rocket and High-Power Rocket Motors,* 2017 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2018 edition.

NFPA 2113, *Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire,* 2020 edition.

2.3 Other Publications.

2.3.1 AMCA Publications. Air Movement and Control Association International, Inc., 30 West University Drive, Arlington Heights, IL 60004-1893.

AMCA 99, *Standards Handbook*, 2016.

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

ASME B31.3, *Process Piping*, 2016.

Boiler and Pressure Vessel Code, 2017.

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

ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, 2012a.

ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air,* 2003, reapproved 2013.

2.3.4 IEC Publications. International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC),* 2012.

2.3.5 ISA Publications. International Society of Automation, 67 T.W. Alexander Drive, 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 — Part 1: Framework, Definitions, System, Hardware and Software Requirements*, 2004.

2.3.6 NEMA Publications. National Electrical Manufacturers Association, 1300 North 17th Street, Suite 900, Arlington, VA 22209.

NEMA 250, *Enclosures for Electrical Equipment*, 2014.

2.3.7 U.S. Government Publications. U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

Title 29, Code of Federal Regulations, Part 1910.242(b), "Hand and Portable Powered Tools and Equipment, General."

2.3.8 Other Publications.

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

Δ **2.4 References for Extracts in Mandatory Sections.**

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2019 edition.
NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2018 edition.
NFPA 77, *Recommended Practice on Static Electricity,* 2019 edition.
NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls,* 2018 edition.
NFPA 484, *Standard for Combustible Metals,* 2019 edition.
NFPA 652, *Standard on the Fundamentals of Combustible Dust,* 2019 edition.
NFPA 921, *Guide for Fire and Explosion Investigations,* 2017 edition.
NFPA 1250, *Recommended Practice in Fire and Emergency Service Organization Risk Management,* 2015 edition.
NFPA 1451, *Standard for a Fire and Emergency Service Vehicle Operations Training Program,* 2018 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. An NFPA Standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase "standards development process" or "standards development activities," the term "standards" includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

Δ **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.

N **3.3.2* Additive Manufacturing.** A process of joining materials to make objects from 3D model data, usually layer upon layer.

3.3.3* Air-Material Separator (AMS). A device designed to separate the conveying air from the material being conveyed. [**652,** 2019]

3.3.4* 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. [**652,** 2019]

3.3.5 Bonding. For the purpose of controlling static electric hazards, the process of connecting two or more conductive objects by means of a conductor so that they are at the same electrical potential but not necessarily at the same potential as the earth. [**652,** 2019]

3.3.6* Centralized Vacuum Cleaning System. A fixed-pipe system utilizing variable-volume negative-pressure (i.e., vacuum) air flows from remotely located hose connection stations to allow the removal of dust accumulations from surfaces and conveying those dusts to an air-material separator (AMS). [**652,** 2019]

3.3.7* Combustible Dust. A finely divided combustible particulate solid that presents a flash-fire hazard or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations. [**652,** 2019]

3.3.8* Combustible Particulate Solid. Any solid material composed of distinct particles or pieces, regardless of size, shape, or chemical composition that, when processed, stored, or handled in the facility, has the potential to produce a combustible dust. [**652,** 2019]

3.3.9 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.

N **3.3.10* Conductive.** Possessing the ability to allow the flow of an electric charge. [**652,** 2019]

N **3.3.10.1** ***Conductive Particulate Solids.*** Particulate solids with a volume resistivity of less than 10^6 ohm-m.

3.3.11* Deflagration. Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium. [**68,** 2018]

3.3.12 Deflagration Hazard Area.

3.3.12.1* ***Dust Explosion Hazard Area.*** A room or building volume where an unvented deflagration of the entrainable dust mass can result in a pressure exceeding the strength of the weakest structural element not intended to fail.

3.3.12.2* ***Dust Flash-Fire Hazard Area.*** An area where combustible dust accumulation on exposed or concealed surfaces, external to equipment or containers, can result in personnel injury from thermal dose during a dust deflagration, as well as any areas where a dust cloud of a hazardous concentration exists.

3.3.13 Detachment. A hazard management strategy in which the hazard is located in a separate building or an outside area, removed from other structures to be protected by a distance as required by this standard.

N **3.3.14* Dissipative.** A material or a construction that will reduce static charge to acceptable levels. [**77,** 2019]

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

3.3.16 Duct. Pipes, tubes, or other enclosures used to convey materials pneumatically or by gravity. [**652,** 2019]

3.3.17* Dust Collection System. A combination of equipment designed to capture, contain, and pneumatically convey fugitive dust to an air-material separator (AMS) in order to remove the dust from the process equipment or surrounding area. [**652,** 2019]

3.3.18 Dust Deflagration Hazard. A condition that presents the potential for harm or damage to people, property, or the environment due to the combustion of a sufficient quantity of combustible dust suspended in air or another oxidizing medium. [**652,** 2019]

3.3.19 Dust Explosion Hazard. A dust deflagration hazard in an enclosure that is capable of bursting or rupturing the enclosure due to the development of internal pressure from the deflagration. [**652,** 2019]

3.3.20* Dust Hazards Analysis (DHA). A systematic review to identify and evaluate the potential fire, flash-fire, and explosion hazards associated with the presence of one or more combustible particulate solids in a process or facility. [**652,** 2019]

3.3.21 Enclosureless Dust Collector. An air-material separator designed and used to remove dust from the transport air where the filter medium is not enclosed or in a container.

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

Δ **3.3.23 Fire Hazard.** Any situation, process, material, or condition that can cause a fire or provide a ready fuel supply to augment the spread or intensity of a fire and poses a threat to life or property. [**652,** 2019]

3.3.24* Flash Fire. A fire that spreads by means of a flame front rapidly through a diffuse fuel, such as dust, gas, or the vapors of an ignitible liquid, without the production of damaging pressure. [**921,** 2017]

3.3.25 Fuel Object. A combustible object or mass of particulate that can serve as a source of fuel for a fire or deflagration; sometimes referred to as a *fuel package.* [**652,** 2019]

3.3.26 Grounding. The process of bonding one or more conductive objects to the ground so that all objects are at zero electrical potential; also referred to as earthing. [**652,** 2019]

3.3.27 Hot Work. Work involving burning, welding, or a similar operation that is capable of initiating fires or explosions. [**51B,** 2019]

3.3.28* Hybrid Mixture. An explosible heterogeneous mixture, comprising gas with suspended solid or liquid particulates, in which the total flammable gas concentration is ≥10 percent of the lower flammable limit (LFL) and the total suspended particulate concentration is ≥10 percent of the minimum explosible concentration (MEC). [**68,** 2018]

3.3.29 Intermediate Bulk Containers.

3.3.29.1* ***Flexible Intermediate Bulk Container (FIBC).*** Large bags typically made from nonconductive woven fabric that are used for storage and handling of bulk solids. [**652,** 2019]

3.3.29.1.1 ***Type A FIBC.*** An FIBC made from nonconductive fabric with no special design features for control of electrostatic discharge hazards. [**652,** 2019]

3.3.29.1.2 ***Type B FIBC.*** An FIBC made from nonconductive fabric where the fabric or the combination of the fabric shell, coating, and any loose liner has a breakdown voltage of less than 6000 volts. [**652,** 2019]

3.3.29.1.3 ***Type C FIBC.*** An FIBC made from conductive material or nonconductive woven fabric incorporating interconnected conductive threads of specified spacing with all conductive components connected to a grounding tab. [**652,** 2019]

3.3.29.1.4 ***Type D FIBC.*** An FIBC made from fabric and/or threads with special static properties designed to control electrostatic discharge energy without a requirement for grounding the FIBC. [**652,** 2019]

3.3.29.2* ***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. [**652,** 2019]

3.3.29.2.1 ***Insulating RIBC.*** An RIBC constructed entirely of solid plastic or solid plastic and foam composite that cannot be electrically grounded. [**652,** 2019]

3.3.30* 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.

3.3.31* 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. [**652,** 2019]

3.3.32* Minimum Ignition Energy (MIE). The lowest capacitive spark energy capable of igniting the most ignition-sensitive concentration of a flammable vapor-air mixture or a combustible dust-air mixture as determined by a standard test procedure. [**652,** 2019]

N **3.3.33 Nanopowder.** See 3.3.48, Ultrafine Particle.

3.3.34* 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.

N **3.3.35* Nonconductive.** A material or a construction that has the ability to accumulate charge, even when in contact with ground. [**652,** 2019]

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

3.3.37* Pneumatic Conveying System. An equipment system that transfers a controlled flow of solid particulate material from one location to another using air or other gases as the conveying medium, and that is comprised of the following components: a material feeding device; an enclosed ductwork, piping, or tubing network; an air-material separator; and an air-moving device. [**652,** 2019]

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

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

N **3.3.38 Portable Vacuum Cleaner.** A movable assembly consisting basically of a vacuum source air-moving device (AMD), an air-material separator (AMS) using either liquid or filter media within an enclosure, and vacuum hose, used to remove dusts and particles from surfaces. [**652,** 2019]

Δ **3.3.39 Pyrophoric Material.** A material that ignites upon exposure to air at or below 130°F (54.4°C). [**484,** 2019]

3.3.40 Qualified Person. A person who, by possession of a recognized degree, certificate, professional standing, or skill, and who, by knowledge, training, and experience, has demonstrated the ability to deal with problems related to the subject matter, the work, or the project. [**1451,** 2018]

3.3.41 Replacement-in-Kind. A replacement that satisfies the design specifications of the replaced item. [**652,** 2019]

3.3.42* Risk Assessment. An assessment of the likelihood, vulnerability, and magnitude of the incidents that could result from exposure to hazards. [**1250,** 2015]

3.3.43 Segregation. A hazard management strategy in which a physical barrier is established between the hazard area and an area to be protected. [**652,** 2019]

3.3.44 Separation. A hazard management strategy achieved by the establishment of a distance as required by the standard between the combustible particulate solid process and other operations that are in the same room. [**652,** 2019]

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

3.3.46 Threshold Housekeeping Dust Accumulations. The maximum quantity of dust permitted to be present before cleanup is required. [**652,** 2019]

3.3.47 Ullage Space. The open space above the surface of the stored solids in a storage vessel. [**652,** 2019]

N **3.3.48* Ultrafine Particle.** Individual particles that have a median size, in two or three dimensions, less than 0.5 μm (500 nm).

3.3.49 Vent Closure. A pressure-relieving cover that is placed over a vent. [**68,** 2018]

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

3.3.51 Wall.

3.3.51.1 ***Fire Barrier Wall.*** A wall, other than a fire wall, having a fire resistance rating. [**221,** 2018]

3.3.51.2 ***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,** 2018]

3.3.52* 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.

3.3.53* 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.

3.3.54* 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

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4.1 Owner's Obligation. The facility owner/operator shall be responsible for ensuring that the facility and the systems handling combustible particulate solids are designed, installed, and maintained in accordance with the requirements of this standard and NFPA 652.

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4.2 Objectives. The objectives stated in this section shall be interpreted as intended outcomes of this standard and not as prescriptive requirements. [**652:**4.2]

4.2.1 Life Safety.

4.2.1.1* The facility, processes, and equipment shall be designed, constructed, equipped, and maintained and management systems shall be implemented to reasonably protect occupants not in the immediate proximity of the ignition from the effects of fire for the time needed to evacuate, relocate, or take refuge. [**652:**4.2.1.1]

4.2.1.1.1 The facility, processes, and equipment shall be designed, constructed, equipped, and maintained and management systems shall be implemented to reasonably prevent serious injury from flash fires. [**652:**4.2.1.2]

4.2.1.1.2 The facility, processes, and equipment shall be designed, constructed, equipped, and maintained and management systems shall be implemented to reasonably prevent serious injury from explosions. [**652:**4.2.1.3]

4.2.1.2 The structure shall be located, designed, constructed, and maintained to reasonably protect adjacent properties and the public from the effects of fire, flash fire, or explosion. [**652:**4.2.1.4]

4.2.2 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.

4.2.3* Mission Continuity. The facility, processes, and equipment, shall be designed, constructed, equipped, and maintained and management systems shall be implemented 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. [**652:**4.2.2]

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

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

4.2.4.2 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.

Δ **4.3* Compliance Options.** The goal in Section 1.3 and the objectives in Section 4.2 shall be achieved by either of the following means:

(1) The prescriptive provisions in accordance with Chapters 5, 7, 8, and 9 of this standard
(2) The performance-based approach in accordance with Chapter 6

N Chapter 5 Hazard Identification

N **5.1 Hazard Identification.** The materials handled in the facility shall be evaluated for their hazard in accordance with Chapter 5 of NFPA 652.

Chapter 6 Performance-Based Design Option

6.1 General Requirements.

N **6.1.1 Retained Prescriptive Requirements.** Portions of a facility designed in accordance with this chapter as an alternative for particular prescriptive requirements shall meet all other relevant prescriptive requirements in this standard. [**652:**6.1.1]

N **6.1.2*** It shall be permitted to use performance-based alternative designs for a process or part of a process, specific material, or piece of equipment in lieu of the prescriptive requirements found in Chapter 9. [**652:**6.1.2]

6.1.3 Approved Qualifications. The performance-based design shall be prepared by a person knowledgeable about the affected systems and their associated hazards and with qualifications acceptable to the owner/operator.

6.1.4* Independent Review. The AHJ shall be permitted to obtain an independent third party review of the proposed design.

6.1.5* 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 in accordance with Section 5.8 of NFPA *101.* The documentation requirements of 5.8.6 shall be supplemented to include documentation of flash fire and explosion scenarios.

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

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

6.1.6* 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.

6.1.7* Sources of Data.

6.1.7.1 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.

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

6.2 Performance Criteria. A system and facility design shall be deemed to meet the objectives specified in Section 4.2 if its performance meets the criteria in 6.2.1 through 6.2.5.

Δ **6.2.1 Occupant Life Safety.**

6.2.1.1 The life safety objectives of 4.2.1 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.

6.2.1.2 The life safety objectives of 4.2.1 with respect to an 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.

6.2.2* Structural Integrity. The structural integrity objective of 4.2.2 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.

6.2.3 Mission Continuity. The mission continuity objectives of 4.2.3 shall be achieved when damage to equipment and the facility has been limited to a level of damage acceptable to the owner/operator.

6.2.4 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.

6.2.5 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

Δ **6.3* Design Scenarios.**

6.3.1 Fire Scenarios.

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

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

6.3.1.3 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.

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

6.3.1.5 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.

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

6.3.1.7 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.

6.3.2 Explosion Scenarios.

6.3.2.1 Each duct, enclosed conveyor, silo, bunker, AMS, or other vessel 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.

6.3.2.2 Each duct, enclosed conveyor, silo, bunker, AMS, 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.

6.3.2.3 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.

6.3.2.4 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.

6.4 Evaluation of Proposed Design.

Δ **6.4.1*** A proposed design's performance shall be assessed relative to each performance objective in Section 4.2 and each applicable scenario in Section 6.3, with the assessment conducted through the use of appropriate calculation methods acceptable to the AHJ.

6.4.2 The design professional shall establish numerical performance criteria for each of the objectives in Section 4.2.

6.4.3 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.

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N Chapter 7 Dust Hazards Analysis (DHA)

N **7.1 General Requirements.**

N **7.1.1** The requirements of this chapter shall be applied retroactively in accordance with 7.1.1.1 through 7.1.1.3. [**652:**7.1.1]

N **7.1.1.1*** A DHA shall be completed for all new processes and facility compartments. [**652:**7.1.1.1]

N **7.1.1.2** For existing processes and facility compartments a DHA shall be completed by September 7, 2020. [**652:**7.1.1.2]

N **7.1.1.3** The owner/operator shall demonstrate reasonable progress each year in completing DHAs prior to the deadline set in 7.1.1.2. [**652:**7.1.1.3]

N **7.1.2** The owner/operator of a facility where materials determined to be combustible or explosible in accordance with Chapter 5 of NFPA 652 are present in an enclosure shall be responsible to ensure a DHA is completed in accordance with the requirements of Chapter 7 of NFPA 652. [**652:**7.1.2]

N **7.1.3** The absence of previous incidents shall not be used as the basis for not performing a DHA. [**652:**7.1.3]

N **7.1.4** The DHA shall be reviewed and updated at least every 5 years. [**652:**7.1.4]

N **7.2 Hazard Assessment.**

N **7.2.1** The facility and process equipment shall be evaluated for dust flash-fire and dust explosion hazards in accordance with this chapter. The hazard assessment shall be conducted in accordance with the retroactivity provisions in Section 7.1.

N **7.2.1.1** Those portions of the process and facility interior where dust accumulations exist external to equipment in sufficient depth to prevent discerning the underlying contrasting surface color shall be evaluated to determine if a dust explosion hazard or flash-fire hazard exists.

N **7.2.1.2** Areas where dust clouds of a hazardous concentration exist shall be deemed to be dust flash-fire and dust explosion hazard areas.

N **7.2.1.3*** Dust flash-fire or dust explosion hazard areas shall additionally be determined in accordance with any one of the following four methods:

(1) Layer depth criterion method in 7.2.3
(2) Mass method A in 7.2.4
(3) Mass method B in 7.2.5
(4) Risk assessment method in 7.2.6

N **7.2.1.4** Each of the methods in 7.2.3, 7.2.4, 7.2.5, and 7.2.6 shall be deemed to provide equivalent levels of safety.

N **7.2.1.5*** It shall be permitted to determine the accumulated mass and bulk density on a dry weight basis by drying the sample to less than or equal to 5 percent moisture by weight.

N **7.2.1.6** Dust accumulations are deemed nonseparated unless segregation, separation, or detachment is used to limit the hazard area in accordance with 9.2.1.

N **7.2.1.7** All dust accumulated on structures above the lowest footprint shall be evaluated as if accumulated on the lowest footprint.

N **7.2.1.8** Dust accumulation amounts shall reflect the conditions that exist just prior to routinely scheduled cleaning and shall not include short-term accumulations cleaned in accordance with Chapter 8.

N **7.2.1.9** The process equipment shall be assessed in accordance with 7.2.7.

N **7.2.1.10** Personnel exposed to a dust flash-fire hazard shall be protected in accordance with 8.8.1.2.

N **7.2.2** Those portions of the facility and process where a dust explosion hazard or flash-fire hazard exists shall be protected from the effects of those hazards in accordance with this section as well as 9.2.1, 9.2.2, and 9.2.3 and Chapter 7.

N **7.2.3* Layer Depth Criterion Method.** A dust flash-fire or dust explosion hazard area exists when the average dust layer thickness measured external to process equipment over the compartment area exceeds the quantity determined in 7.2.3.1 and 7.2.3.2.

N **7.2.3.1** The layer depth criterion, which is $\frac{1}{32}$ in. (0.8 mm), shall be permitted to be increased according to the following equation for materials with bulk density less than 75 lb/ft^3 (1200 kg/m^3):

N **[7.2.3.1]**

$$LD\ (\text{in.}) = \frac{\left(\frac{1}{32}\ \text{in.}\right)\left(75\ \frac{\text{lb}}{\text{ft}^3}\right)}{BD}$$

where:
LD = layer depth (in.)
BD = bulk density (lb/ft^3)

N **7.2.3.2*** A dust explosion hazard and dust flash-fire hazard shall be deemed to exist in any building or room where any of the following conditions exists:

(1) The total area of nonseparated dust accumulations exceeding the layer depth criterion is greater than 5 percent of the footprint area

(2) The area of any single nonseparated dust accumulation exceeding the layer depth criterion is greater than 1000 ft^2 (92.9 m^2)
(3) The total volume of nonseparated dust accumulations is greater than the layer depth criterion multiplied by 5 percent of the footprint area
(4) The total volume of any single nonseparated dust accumulation is greater than the layer depth criterion multiplied by 1000 ft^2 (92.9 m^2)

N **7.2.4* Mass Method A.** A dust flash-fire or dust explosion hazard area exists when the total accumulated dust external to process equipment exceeds the quantities determined from the equations in 7.2.4.1 and 7.2.4.2.

N **7.2.4.1** The threshold dust mass establishing a building or room as a dust explosion hazard area, $M_{basic\text{-}exp}$, shall be determined by the following equation:

N **[7.2.4.1]**

$$M_{basic\text{-}exp} = 0.004 \cdot A_{floor} \cdot H$$

where:
$M_{basic\text{-}exp}$ = threshold dust mass (kg) based on building damage criterion
A_{floor} = lesser of enclosure floor area (m^2) or 2000 m^2
H = lesser of enclosure ceiling height (m) or 12 m

N **7.2.4.2** The threshold dust mass establishing a building or room as a dust flash-fire hazard area, $M_{basic\text{-}fire}$, shall be determined by the following equation:

N **[7.2.4.2]**

$$M_{basic\text{-}fire} = 0.02 \cdot A_{floor}$$

where:
$M_{basic\text{-}fire}$ = threshold dust mass (kg) based on personnel fire exposure criterion
A_{floor} = lesser of enclosure floor area (m^2) or 2000 m^2

N **7.2.5* Mass Method B.** A dust flash-fire or dust explosion hazard area exists when the total accumulated dust external to process equipment exceeds the quantities determined from the equations in 7.2.5.1 and 7.2.5.2.

N **7.2.5.1*** The threshold dust mass establishing a building or room as a dust explosion hazard area, M_{exp}, shall be determined by the following equation:

N **[7.2.5.1]**

$$M_{exp} = \left[\frac{P_{es}}{DLF}\right] \cdot \left[\frac{C_w}{P_{max}}\right] \cdot \frac{A_{floor} \cdot H}{\eta_D}$$

where:
M_{exp} = threshold dust mass (kg) based on building damage criterion
P_{es} = enclosure strength evaluated based on static pressure calculations for the weakest building structural element not intended to vent or fail (bar g) per NFPA 68
DLF = dynamic load factor, the ratio of maximum dynamic deflection to static deflection per NFPA 68
C_w = worst-case dust concentration (kg/m^3) at which the maximum rate-of-pressure-rise results in tests conducted per ASTM E1226
P_{max} = maximum pressure (bar g) developed in ASTM E1226 tests with the accumulated dust sample
A_{floor} = enclosure floor area (m^2)
H = enclosure ceiling height (m)
η_D = entrainment fraction = 0.25

N **7.2.5.1.1** In the absence of detailed structural response analysis, it shall be permitted to assume a worst-case value of DLF = 1.5 and design based on the weakest structural element of the enclosure.

N **7.2.5.1.2*** It shall be permitted to use an alternative value of η_D based on a risk assessment that is acceptable to the AHJ.

N **7.2.5.2*** The threshold dust mass establishing a building or room as a dust flash-fire hazard area, M_{fire}, shall be determined by the following equation:

N **[7.2.5.2]**

$$M_{fire} = \rho \cdot C_w \cdot \left[\frac{P_{initial}}{P_{initial} + P_{max}}\right] \cdot \frac{A_{floor} \cdot D}{\eta_D}$$

where:
M_{fire} = threshold dust mass (kg) based on personnel fire exposure criterion
ρ = probability of flame impingement on a person, not to exceed 0.05 (5 percent probability)
C_w = worst-case dust concentration (kg/m^3) at which the maximum rate-of-pressure-rise results in tests conducted per ASTM E1226
$P_{initial}$ = 1 bar absolute
P_{max} = maximum pressure (bar g) developed in ASTM E1226 tests with the accumulated dust sample
A_{floor} = enclosure floor area (m^2)
D = nominal height of a person (2 m)
η_D = entrainment fraction = 0.25

N **7.2.5.2.1*** It shall be permitted to use an alternative value of η_D, based on a risk assessment that is acceptable to the AHJ.

N **7.2.6* Risk Assessment Method.** A documented risk assessment acceptable to the AHJ shall be permitted to be conducted to determine whether or where a dust explosion hazard or dust flash-fire hazard area exists.

N **7.2.7** An explosion hazard shall be deemed to exist in enclosed process equipment where both of the following conditions are possible:

(1) Combustible dust is present in sufficient quantity to cause enclosure rupture if suspended and ignited.
(2) A means of suspending the dust is present.

Δ Chapter 8 Management Systems

N **8.1 Retroactivity.** This chapter shall be applied retroactively to new and existing facilities and processes.

N **8.2 General. (Reserved)**

N **8.3 Operating Procedures.** See 8.8.1.

Δ 8.4 Housekeeping Procedures and Portable Vacuum Cleaners.

8.4.1 Cleaning Frequency.

8.4.1.1* Where the facility is intended to be operated with less than the dust accumulation defined by the owner/operator's chosen criterion in Section 7.2, the housekeeping frequency shall be established to ensure that the accumulated dust levels on walls, floors, and horizontal surfaces such as equipment, ducts, pipes, hoods, ledges, beams, and above suspended ceilings and other concealed surfaces, such as the interior of electrical enclosures, does not exceed the threshold dust mass/accumulation.

8.4.1.2 Where the facility is intended to be operated with less than the dust accumulation defined by the owner/operator's chosen criterion in Section 7.2, a planned inspection process shall be implemented to evaluate dust accumulation rates and the housekeeping frequency required to maintain dust accumulations below the threshold dust mass/accumulation.

8.4.1.3* Where the facility is intended to be operated with less than the dust accumulation defined by the owner/operator's chosen criterion in Section 7.2, the housekeeping procedure shall include specific requirements establishing time to clean local spills or short-term accumulation to allow the elimination of the spilled mass or accumulation from the calculations in Section 7.2.

Δ **8.4.1.4*** Where the facility is intended to be operated with more than the dust accumulation defined by the owner/operator's chosen criterion in Section 7.2, a documented risk assessment acceptable to the AHJ shall be permitted to be conducted to determine the level of housekeeping consistent with any dust explosion and dust flash-fire protection measures provided in accordance with 9.2.3 and 8.8.1.2.

8.4.2 Cleaning Methods.

8.4.2.1 Surfaces shall be cleaned in a manner that minimizes the risk of generating a fire or explosion hazard.

8.4.2.2 Vacuuming shall be the preferred method of cleaning.

8.4.2.3 Where vacuuming is impractical, permitted cleaning methods shall include sweeping and water washdown.

8.4.2.4* Blowdowns using compressed air or steam shall be permitted to be used for cleaning inaccessible surfaces or surfaces where other methods of cleaning result in greater personal safety risk. Where blowdown using compressed air is used, the following precautions shall be followed:

(1) Vacuuming, sweeping, or water washdown methods are first used to clean surfaces that can be safely accessed prior to using compressed air.
(2) Dust accumulations in the area after vacuuming, sweeping, or water washdown do not exceed the threshold dust accumulation.
(3) Compressed air hoses are equipped with pressure relief nozzles limiting the discharge gauge pressure to 30 psi (207 kPa) in accordance with the OSHA requirements in 29 CFR 1910.242(b), "Hand and Portable Powered Tools and Equipment, General."
(4) All electrical equipment potentially exposed to airborne dust in the area meets, as a minimum, the requirements of *NFPA 70*; NEMA 12 as defined by NEMA 250, *Enclosures for Electrical Equipment*; or the equivalent.
(5) All ignition sources and hot surfaces capable of igniting a dust cloud or dust layer are shut down or removed from the area.

8.4.2.5* Housekeeping procedures shall be documented in accordance with the requirements of Sections 7.1 and 8.12.

Δ **8.4.3* Portable Vacuum Cleaners.**

N **8.4.3.1** Portable vacuum cleaners with a dirty side volume greater than 8 ft^3 shall comply with 9.7.1 and 9.7.2. [**652:**8.4.2.2.1.1]

N **8.4.3.2*** When metal particles, dusts, or powders are being cleaned NFPA 484 shall be the reference source for proper use and limitations of both dry and wet portable vacuum cleaners. [**652:**8.4.2.2.1.2]

N **8.4.3.3*** The operation of portable vacuum cleaning devices shall be subject to a dust hazard analysis to ensure that the risk to personnel and facility operations from deflagrations is minimized. [**652:**8.4.2.2.1.3]

N **8.4.3.4** Hoses and vacuum tools shall be appropriate for use and be static dissipative or conductive. [**652:**8.4.2.2.1.4]

N **8.4.3.5** Portable vacuum cleaners shall not be used on processes generating hot embers or sparks. [**652:**8.4.2.2.1.5]

N **8.4.3.6*** For portable vacuum cleaners used with combustible dusts having a minimum ignition energy less than 30 mJ, the path to ground shall be verified prior to use after each movement or new connection, or both. [**652:**8.4.2.2.1.6]

8.4.3.7* Portable vacuum cleaners that meet the following minimum requirements shall be permitted to be used to collect combustible particulate solids in unclassified (general purpose) areas:

(1) Materials of construction shall comply with 9.3.13.2 and 9.4.3.2.
(2) Hoses shall be conductive or static dissipative.
(3) All conductive components, including wands and attachments, shall be bonded and grounded.
(4) Dust-laden air shall not pass through the fan or blower.
(5) Electrical motors shall not be in the dust-laden air stream unless listed for Class II, Division 1, locations.
(6)* When liquids or wet material are picked up by the vacuum cleaner, paper filter elements shall not be used.
(7) Vacuum cleaners used for metal dusts shall meet the requirements of NFPA 484.

Δ **8.4.3.8*** In Class II electrically classified (hazardous) locations, vacuum cleaners shall be listed for the purpose and location or shall be a fixed-pipe suction system with remotely located exhauster and AMS installed in conformance with 9.3.13 and shall be suitable for the dust being collected.

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

N 8.5 Open Flames and Sparks (Hot Work).

N **8.5.1** Cutting and welding shall comply with the applicable requirements of NFPA 51B.

N **8.5.2** 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.

N **8.5.3** Smoking shall be permitted only in designated areas.

N **8.6 Personal Protective Equipment (PPE).** See 8.8.1.

N **8.7 Inspection and Maintenance.**

N **8.7.1 General Requirements.**

N **8.7.1.1** 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.

N **8.7.1.2** 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

N **8.7.1.3** Records shall be kept of maintenance and repairs performed.

N **8.7.2 Specific Requirements.**

N **8.7.2.1 Maintenance of Material Feeding Devices.**

N **8.7.2.1.1** Bearings shall be lubricated and checked for excessive wear on a periodic basis.

N **8.7.2.1.2** 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.

N **8.7.2.2 Maintenance of Air-Moving Devices.**

N **8.7.2.2.1** Fans and blowers shall be checked periodically for excessive heat and vibration.

N **8.7.2.2.2** Maintenance, other than the lubrication of external bearings, shall not be performed on fans or blowers while the unit is operating.

N **8.7.2.2.3** Bearings shall be lubricated and checked periodically for excessive wear.

N **8.7.2.2.4*** 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.

N **8.7.2.2.5*** The surfaces of fan housings and other interior components shall be maintained free of rust.

N **8.7.2.2.6** Aluminum paint shall not be used on interior steel surfaces.

N **8.7.2.3 Maintenance of Air-Material Separators.**

N **8.7.2.3.1 Means to Dislodge.**

N **8.7.2.3.1.1** 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.

N **8.7.2.3.1.2** These devices shall be adjusted and lubricated as recommended in the manufacturers' instructions.

N **8.7.2.3.2** AMSs that recycle air (i.e., cyclones and filter media dust collectors) shall be maintained to comply with 9.3.13.1.6.3.

N **8.7.2.3.3** 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.

N **8.7.2.4 Maintenance of Abort Gates and Abort Dampers.** Abort gates and abort dampers shall be adjusted and lubricated as recommended in the manufacturers' instructions.

N **8.7.2.5 Maintenance of Fire and Explosion Protection Systems.**

N **8.7.2.5.1** All fire detection equipment monitoring systems shall be maintained in accordance with the requirements of *NFPA 72*.

N **8.7.2.5.2** All fire-extinguishing systems shall be maintained pursuant to the requirements established in the standard that governs the design and installation of the system.

N **8.7.2.5.3*** All vents for the relief of pressure caused by deflagrations shall be maintained.

N **8.7.2.5.4** All explosion prevention systems and inerting systems shall be maintained pursuant to the requirements of NFPA 69.

N **8.7.3 Impairments of Fire Protection and Explosion Prevention Systems.**

N **8.7.3.1*** Impairments shall include anything that interrupts the normal intended operation of the fire protection or explosion prevention system.

N **8.7.3.2*** A written impairment procedure shall be followed for every impairment to the fire protection or explosion prevention system.

N **8.7.3.3*** Impairments shall be limited in size and scope to the system or portion thereof being repaired, maintained, or modified.

N **8.7.3.4*** Impairment notification procedures shall be implemented by management to notify plant personnel and the AHJ of existing impairments and their restoration.

N **8.8 Employee Training and Procedures.**

N **8.8.1 Plan.**

N **8.8.1.1** Operating and maintenance procedures shall be developed.

N **8.8.1.2*** Operating and maintenance procedures shall address personal protective equipment (PPE), including flame-resistant garments, in accordance with the workplace hazard assessment required by NFPA 2113.

N **8.8.1.3** The plans and procedures shall be reviewed annually and as required by process changes.

N **8.8.2 Initial and Refresher Training.**

N **8.8.2.1** Initial and refresher training shall be provided to employees who are involved in operating, maintaining, and supervising facilities that handle combustible particulate solids.

N **8.8.2.2** 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

N **8.8.3 Certification.** The employer shall certify annually that the training and review required by 8.8.1 and 8.8.2 have been completed.

N **8.9 Contractors and Subcontractors.**

N **8.9.1 General.** Owner/operators shall ensure that the requirements of 8.9.1.1 through 8.9.2.5 are met.

N **8.9.1.1*** Only qualified contractors possessing the requisite craft skills shall be employed for work involving the installation, repair, or modification of buildings (interior and exterior), machinery, and fire protection equipment.

N **8.9.1.2** Contractors involved in the commissioning, repair, or modification of explosion protection equipment shall be qualified as specified in Chapter 15 of NFPA 69.

N **8.9.2 Contractor Training.**

N **8.9.2.1** Contractors operating owner/operator equipment shall be trained and qualified to operate the equipment and perform the work.

N **8.9.2.2** Written documentation shall be maintained detailing the training that was provided and who received it.

N **8.9.2.3** Contractors working on or near a given process shall be made aware of the potential hazards from and exposures to fire, explosion, or toxic releases.

N **8.9.2.4*** Contractors shall be trained and required to comply with the facility's safe work practices and policies, including but not limited to equipment lockout/tagout permitting, hot work permitting, fire system impairment handling, smoking, housekeeping, and use of PPE.

N **8.9.2.5** Contractors shall be trained on the facility's emergency response and evacuation plan, including but not limited to emergency reporting procedures, safe egress points, and evacuation areas.

N **8.10 Emergency Planning and Response.**

N **8.10.1** A written emergency response plan shall be developed for preventing, preparing for, and responding to work-related emergencies including but not limited to fire and explosion.

N **8.10.2** The plans and procedures shall be reviewed annually and as required by process changes.

N **8.11 Incident Investigation.**

N **8.11.1*** Incidents that result in a fire or explosion of a magnitude that causes property damage, production shutdown time, or injury shall be investigated.

N **8.11.2** Once the scene has been released by the AHJ, incident investigations shall be promptly initiated by management personnel or by a designee who has a working knowledge of the facility and processes.

N **8.11.3*** A written report of the investigation shall be prepared that describes the incident, lists what has been learned from the investigation, and makes recommendations to prevent recurrence of that or similar incidents.

N **8.11.4*** A summary of the incident investigation report shall be shared with affected personnel operating, maintaining, and supervising the facility.

N **8.12* Management of Change.** Written procedures shall be established and implemented to manage proposed changes to process materials, staffing, job tasks, technology, equipment, procedures, and facilities. [**652:**8.12.1]

N **8.12.1** The management of change procedure 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, including the authorized duration of the temporary change
(4) Modifications to operating and maintenance procedures
(5) Employee training requirements
(6) Authorization requirements for the proposed change
(7) Results of characterization tests used to assess the hazard, if conducted

N **8.12.2** Implementation of the management of change procedure shall not be required for replacements-in-kind. [**652:**8.12.3]

N **8.12.3** Design documentation, as required by 9.1.2 and procedures shall be updated to incorporate the change.

N **8.13 Document Retention. (Reserved)**

N **8.14 Management Systems Review. (Reserved)**

N **8.15 Employee Participation. (Reserved)**

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N Chapter 9 Hazard Management: Mitigation and Prevention

N **9.1 Process and Facility Design.**

N **9.1.1** 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.

N **9.1.2*** The design and its basis shall be documented and maintained for the life of the process.

N **9.2 Building Design.**

N **9.2.1 Segregation, Separation, or Detachment of Combustible Dust Handling and Processing Areas.**

N **9.2.1.1 General.** Areas in which combustible dusts are produced, processed, handled, or collected such that combustible dust accumulation on exposed or concealed surfaces, external to equipment or containers, exceeds the threshold as determined in Section 7.2, shall be detached, segregated, or separated from other occupancies to minimize damage from a fire or explosion.

N **9.2.1.2 Use of Segregation.**

N **9.2.1.2.1*** Physical barriers that are erected to segregate dust flash-fire hazards areas, including seals at all penetrations of floors, walls, ceilings, or partitions, shall have a minimum 1-hour fire resistance rating.

N **9.2.1.2.2** Physical barriers that are erected to segregate dust explosion hazard areas shall be designed to preclude failure of those barriers during a dust explosion per NFPA 68.

N **9.2.1.2.3** Doors and openings shall not be permitted in physical barriers unless they are normally are closed and have at least the strength and fire resistance rating required of the physical barrier. These doors shall be installed according to NFPA 80.

N **9.2.1.3 Use of Separation.**

N **9.2.1.3.1*** Separation shall be permitted to be used to limit the dust explosion hazard or dust flash-fire hazard area where supported by a documented engineering evaluation acceptable to the AHJ.

N **9.2.1.3.1.1** The required separation distance between the dust explosion hazard or flash-fire hazard area identified in Section 7.2 and surrounding exposures shall be determined by an engineering evaluation that addresses the following:

(1) Properties of the materials
(2) Type of operation
(3) Amount of material likely to be present external to process equipment
(4) Building and equipment design
(5) Nature of surrounding exposures

N **9.2.1.3.1.2** The separation area either shall be free of dust or, where dust accumulations exist on any surface, the surface colors below shall be readily discernible.

N **9.2.1.3.1.3** Where separation is used to limit the dust flash-fire or dust explosion hazard area determined in Section 7.2, the minimum separation distance shall not be less than 35 ft (11 m), consistent with NFPA 51B.

N **9.2.1.3.2*** Where 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 dust explosion hazard or flash-fire hazard area.

N **9.2.1.3.3** Where separation is used to limit a dust explosion hazard or dust flash-fire hazard area, dust thresholds in Section 7.2 shall be determined for this limited area such that the parameter A_{floor} in the equations in Section 7.2 is consistent with the limited area under consideration.

N **9.2.2 Building Construction.**

N **9.2.2.1** All buildings shall be of Type I or Type II construction, as defined in NFPA 220.

N **9.2.2.2** Where local, state, or national building codes are more restrictive, modifications shall be permitted for conformance to those codes.

N **9.2.2.3*** Interior surfaces where dust accumulations can occur shall be designed and constructed so as to facilitate cleaning and to minimize combustible dust accumulations.

N **9.2.2.4** Spaces inaccessible to housekeeping shall be sealed to prevent dust accumulation.

N **9.2.2.5** Interior walls erected for the purpose of limiting fire spread shall be designed in accordance with NFPA 221 and have a minimum 1-hour fire resistance rating.

N **9.2.2.6 Fire Doors.**

N **9.2.2.6.1** Openings in fire walls and in fire barrier walls shall be protected by self-closing fire doors that have a fire protection rating, when tested in accordance with NFPA 252, equivalent to the wall design.

N **9.2.2.6.2** Fire doors shall be installed according to NFPA 80 and shall normally be in the closed position.

N **9.2.2.7 Egress.** Means of egress shall comply with NFPA *101.*

N **9.2.2.7.1*** Means of egress for buildings or building compartments that contain a deflagration hazard area shall be designed in accordance with Section 7.11 of NFPA *101.*

N **9.2.2.8 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 resistance rating and their physical integrity in a deflagration. *(See 9.3.6.5.)*

N **9.2.2.9 Fire Resistance Rating.**

N **9.2.2.9.1*** Interior stairs and elevators shall be enclosed in shafts designed to prevent the migration of dust and that have a minimum fire resistance rating of in accordance with Section 8.6 of NFPA *101.*

N **9.2.2.9.2*** Doors that are the automatic-closing or self-closing type and that have a minimum fire protection rating of 1 hour shall be provided at each landing.

N **9.2.2.9.3** Stairs, elevators, and manlifts that serve only open-deck floors, mezzanines, and platforms shall not be required to be enclosed.

N **9.2.2.10*** Floors and load-bearing walls that are exposed to dust explosion hazards shall be designed to preclude failure during an explosion.

N **9.2.3* Deflagration Venting of Buildings or Building Compartments.**

N **9.2.3.1*** If a building or building compartment contains a dust explosion hazard area external to protected equipment as specified in 7.2.1.2 or 7.2.1.3, the building or building compartment shall be provided with deflagration venting in accordance with NFPA 68.

N **9.2.3.2* Vent Closures.**

N **9.2.3.2.1** Vent closures shall be directed toward a restricted area.

N **9.2.3.2.2** The vent closure shall not be a missile hazard.

N **9.2.3.2.3** The fireball and the blast pressure that are created by the venting process shall not impinge on unrestricted personnel pathways.

N **9.3 Equipment Design.**

N **9.3.1* General.**

N **9.3.1.1** Equipment shall be maintained and operated in a manner that minimizes the escape of dust.

N **9.3.1.2** Methods of fire and explosion protection for specific equipment shall be in accordance with this section.

N **9.3.1.3* Risk Assessment.** A documented risk assessment acceptable to the AHJ shall be permitted to be conducted to determine the level of protection to be provided per this chapter.

N **9.3.1.4*** Systems for the pre-deflagration detection and control of ignition sources, installed in accordance with NFPA 69 shall be permitted to be used to reduce the probability of occurrence of a deflagration in the following:

(1) In ductwork supplying AMS
(2) In recycled air from AMS to a building
(3) In ductwork between process equipment

N **9.3.2 Bulk Storage Enclosures.**

N **9.3.2.1 General.**

N **9.3.2.1.1** For the purposes of this section, bulk storage shall include items such as bins, tanks, hoppers, and silos.

N **9.3.2.1.2*** The requirements of this section shall not apply to containers that are used for transportation of the material.

N **9.3.2.2* 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.

N **9.3.2.3 Explosion Hazards.**

N **9.3.2.3.1** Where an explosion hazard exists, intertank or interbin venting shall not be permitted.

N **9.3.2.3.2 Fixed Bulk Storage Location.**

N **9.3.2.3.2.1** Where an explosion hazard exists, fixed bulk storage containers shall be located outside of buildings.

N **9.3.2.3.2.2** Fixed bulk storage containers shall be permitted to be located inside buildings where one of the following applies:

(1) Fixed bulk storage containers are protected in accordance with 9.7.1.
(2)* Fixed bulk storage containers are less than 8 ft^3 (0.2 m^3).

N **9.3.2.3.3 Fixed Bulk Storage Protection.**

N **9.3.2.3.3.1** Where an explosion hazard exists, fixed bulk storage containers shall be protected in accordance with 9.7.1.

N **9.3.2.3.3.2*** The explosion protection requirements of 9.7.1 shall not be required provided that the volume of the fixed bulk storage container is less than 8 ft^3 (0.2 m^3).

N **9.3.2.3.3.3** The requirements of 9.3.2.3.3 shall not apply to storage and receiving containers that are used for transportation of the material.

N **9.3.2.4* Interior Surfaces.** Interior surfaces shall be designed and constructed to facilitate cleaning and to minimize combustible dust accumulation.

N **9.3.2.5* Access Doors and Openings.**

N **9.3.2.5.1** Access doors or openings shall be provided to allow inspection, cleaning, and maintenance.

N **9.3.2.5.2** Access doors or openings shall be designed to prevent dust leaks.

N **9.3.2.5.3** Access doors or openings that are not specifically designed for deflagration venting shall not be considered as providing that function.

N **9.3.2.5.4** Access doors shall be bonded and grounded.

N **9.3.2.5.5** Access doors not designed to be used as deflagration vents shall be designed to withstand the vented explosion pressure (P_{red}).

N **9.3.3 Material Transfer System.**

N **9.3.3.1 General.**

N **9.3.3.1.1*** Where more than one material is to be handled by a system, compatibility tests shall be run.

N **9.3.3.1.2** Where incompatibility is found, provisions shall be made for cleaning the system prior to transporting a new material.

N **9.3.3.1.3** Where the materials being conveyed are corrosive, the system shall be constructed of corrosion-resistant materials.

N **9.3.3.1.4** Where the atmosphere surrounding the conveying system is corrosive, the conveying system shall be constructed of corrosion-resistant materials.

N **9.3.3.1.5*** 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.

N **9.3.3.2* Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.**

N **9.3.3.2.1** The design of the system shall be documented, and the documentation shall include the following information:

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

N **9.3.3.2.2*** Existing systems shall not be modified without considering the effects of those changes on the system performance, including the redesign of the system to incorporate the proposed changes.

N **9.3.3.2.3** All system components that handle combustible particulate solids shall be designed to be dusttight, except for openings designed for intake and discharge of air and material.

N **9.3.3.2.4*** The system shall be designed and maintained to ensure that the air/gas velocity during operation shall at all times meet or exceed the minimum required to keep the interior surfaces of all piping free of particulate accumulations.

N **9.3.3.2.5* Pneumatic Conveying Systems.** Where a pneumatic conveying system operates at a gauge pressure of 15 psi (103 kPa) or greater, the components exposed to that pressure under normal or upset conditions shall be designed in accordance with Section VIII of the ASME *Boiler and Pressure Vessel Code* or ASME B31.3, *Process Piping*.

N **9.3.3.2.5.1*** Where a pneumatic conveying system or any part of such a system operates as a positive pressure–type system and the AMD'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*; ASME B31.3, *Process Piping* or an international equivalent.

N **9.3.3.2.6 Dust Collection Systems.**

N **9.3.3.2.6.1*** At each collection point, the system shall be designed to achieve the minimum required face velocity for dust capture over the entire opening of the hood or pickup point.

N **9.3.3.2.6.2*** The volumetric flow rate for each collection point shall be included in the system design documentation.

N **9.3.3.2.6.3*** The rate of airflow at each hood or pickup point for each dust source shall be designed so as to convey and control the collected dust.

N **9.3.3.2.6.4*** 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.

N **9.3.3.2.6.5*** Branch lines shall not be added to an existing system without reviewing the design of the entire system.

N **9.3.3.2.6.6*** 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.

N **9.3.3.2.6.7** Dust collection systems that remove material from operations that generate flames, sparks, or hot material shall not be interconnected with dust collection systems that transport combustible particulate solids or hybrid mixtures.

N **9.3.3.2.6.8*** Heating, ventilation, and air conditioning (HVAC) systems shall not be used as the means to collect dusts from localized sources.

N **9.3.3.2.7* Centralized Vacuum Cleaning Systems.**

N **9.3.3.2.7.1*** The system shall be designed to ensure minimum transport velocities at all times.

N **9.3.3.2.7.2*** The system shall be operated only with the hoses and tools that have been designated in the design documentation for the specific hose connection station.

N **9.3.3.2.7.3*** Vacuum hose, couplings, and tools shall be made of conductive or static-dissipative materials that are bonded and grounded in accordance with 9.4.3.2.3.

N **9.3.3.2.7.4*** Controls shall be provided to prevent overfilling the AMS, which could disable the system.

N **9.3.3.2.7.5** The maximum number of hose connection stations that can be simultaneously used shall be included in the system documentation.

N **9.3.3.3* Operations.**

N **9.3.3.3.1 Sequence of Operation.** Pneumatic conveying, dust collection, and centralized vacuum cleaning systems shall be designed with the operating logic, sequencing, and timing outlined in 9.3.3.3.2 and 9.3.3.3.3.

N **9.3.3.3.2* Startup.** Pneumatic conveying, dust collection, and centralized vacuum cleaning 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.

N **9.3.3.3.3 Shutdown.**

N **9.3.3.3.3.1** Pneumatic conveying, dust collection, and centralized vacuum cleaning systems shall be designed such that, on normal shutdown of the process, the system maintains design air velocity until material is purged from the system.

N **9.3.3.3.3.2** The requirements of 9.3.3.3.3.1 shall not apply during emergency shutdown of the process, such as by activation of an emergency stop button or by activation of an automatic safety interlocking device.

N **9.3.3.3.3.3** Dilute phase pneumatic conveying systems shall be designed such that, upon restart after an emergency shutdown, residual materials can be cleared and design air velocity can be achieved prior to admission of new material to the system.

N **9.3.4 Specific Requirements for Systems that Convey Metal Particulates.**

N **9.3.4.1 General.** This section shall apply to facilities that operate pneumatic conveying, dust collection, and centralized vacuum cleaning systems for metal particulates.

N **9.3.4.2** Systems handling metal particulates shall be designed in accordance with NFPA 484 in addition to the requirements of this section.

N **9.3.4.3* Water Reactivity.**

N **9.3.4.3.1** Unless otherwise determined, metal particulates shall be deemed water-reactive, and water-based extinguishing agents shall not be used.

N **9.3.4.3.2** Specially engineered high-density water spray systems approved by the AHJ shall be permitted to be used.

N **9.3.4.3.3** The requirement of 9.3.4.3.1 shall not apply to the collection of iron dusts from shot blasting.

N **9.3.4.4** 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.

N **9.3.4.5 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 AHJ.

N **9.3.5 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 9.7.1.1(1) through 9.7.1.1(4).

N **9.3.6 Duct Systems.**

N **9.3.6.1** Ducts that handle combustible particulate solids shall conform to the requirements of NFPA 91 except as amended by the requirements of this chapter.

N **9.3.6.2** Ductwork shall be constructed of metal or noncombustible, conductive material in accordance with 9.4.3.2.

N **9.3.6.3*** Flexible hose and connections shall be permitted in the minimum length necessary to achieve functions such as but not limited to material pickup, material transfer, vibration isolation, weigh bin isolation, or equipment movement in accordance with 9.4.3.

N **9.3.6.4*** 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.

N **9.3.6.5*** 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.

N **9.3.7 Sight Glasses.**

N **9.3.7.1** Sight glasses shall be of a material that is impact and erosion resistant.

N **9.3.7.2** Sight glass assemblies shall have a pressure rating equal to or greater than that of the ductwork.

N **9.3.7.3** 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.

N **9.3.7.4** The mechanical strength of the sight glass–mounting mechanism shall be equal to the adjoining ductwork.

N **9.3.7.5** The inside diameter of a sight glass shall not cause a restriction of flow.

N **9.3.7.6** The connections between the sight glass and the ductwork shall be squarely butted and sealed so as to be both airtight and dusttight.

N **9.3.7.7** The electrical bonding across the length of the sight glass shall be continuous and have a resistance of no more than 1 ohm.

N **9.3.8 Pressure Protection Systems.**

N **9.3.8.1 Vacuum Breakers.** Vacuum breakers shall be installed on negative-pressure systems if the pressure system is not designed for the maximum vacuum attainable.

N **9.3.8.2* Pressure Relief Devices.**

N **9.3.8.2.1** Pressure relief devices for relief of pneumatic overpressure shall be installed on positive-pressure systems.

N **9.3.8.2.2** The requirement of 9.3.8.2.1 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.*

N **9.3.8.2.3** The requirement of 9.3.8.2.1 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.

N **9.3.8.2.4*** Pressure relief devices shall not be vented to an area where a dust explosion hazard or dust flash-fire hazard exists, as specified by Section 7.2.

N **9.3.8.3 Airflow Control Valves.**

N **9.3.8.3.1** Airflow control valves that are installed in pneumatic conveying, dust collection, or centralized vacuum cleaning systems shall be of both airtight and dusttight construction.

N **9.3.8.3.2** Airflow control valves shall be sized to allow passage of the total airflow of the system when the damper is fully open.

N **9.3.8.3.3** The position of airflow control valves shall be visually indicated.

N **9.3.8.3.4** 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.

N **9.3.8.3.5** Diverter valves shall effect a positive diversion of the material and shall mechanically seal all other directions from air or material leakage.

N **9.3.9 Material Feeding Devices.**

N **9.3.9.1 Mechanical Feeding Devices.**

N **9.3.9.1.1** Mechanical feeding devices shall be equipped with a shear pin or overload detection device and alarm.

N **9.3.9.1.2** The alarm shall sound at the operator control station.

N **9.3.9.2 Drives.**

N **9.3.9.2.1** All drives used in conjunction with feeders, air locks, and other material feeding devices shall be directly connected.

N **9.3.9.2.2** 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.

N **9.3.10* Bucket Elevators.**

N **9.3.10.1 Deflagration Protection.**

N **9.3.10.1.1** Where an explosion hazard exists, bucket elevators shall be protected in accordance with 9.7.1.

N **9.3.10.2** Elevator casings, head and boot sections, and connecting ducts shall be dusttight and shall be constructed of noncombustible materials.

N **9.3.10.3** Where provided, inlet and discharge hoppers shall be designed to be accessible for cleaning and inspection.

N **9.3.10.4 Power Cutoff.**

N **9.3.10.4.1*** 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.

N **9.3.10.4.2** Feed to the elevator leg shall be stopped or diverted when the power to the motor is stopped.

N **9.3.10.5 Belts.**

N **9.3.10.5.1** Belt-driven bucket elevators shall have a nonslip material (lagging) installed on the head pulley to minimize slippage.

N **9.3.10.5.2*** Belts and lagging shall be fire and oil resistant.

N **9.3.10.6** No bearings shall be located in the bucket elevator casing.

N **9.3.10.7*** Head and boot sections shall be provided with openings to allow for cleanout, inspection, and alignment of the pulley and belt.

N **9.3.10.8 Drive.**

N **9.3.10.8.1*** 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.

N **9.3.10.8.2** The drive shall be capable of starting the unchoked elevator under full (100 percent) load.

N **9.3.10.9 Monitors.**

N **9.3.10.9.1** Elevator head and tail pulleys shall be monitored for high bearing temperature, pulley alignment, and belt alignment.

N **9.3.10.9.2** Abnormal conditions shall actuate an alarm requiring corrective action.

N **9.3.10.9.3** The alarm shall sound at the operator control station.

N **9.3.10.10 Emergency Controls.**

N **9.3.10.10.1** 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.

N **9.3.10.10.2** The audible alarm specified in 9.3.10.10.1 shall sound at the operator control station.

N **9.3.11* Enclosed Conveyors.**

N **9.3.11.1 Housing and Coverings.**

N **9.3.11.1.1** Where an explosion hazard exists within enclosed conveyors, they shall be protected in accordance with 9.7.1.

N **9.3.11.1.2** 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.

N **9.3.11.1.2.1** Flexible screw conveyors utilizing nonmetal housing shall be permitted to be used provided the requirements of 9.4.3.2.2 are met.

N **9.3.11.1.3** Coverings on cleanout, inspection, and other openings shall be fastened to prevent the escape of combustible dusts.

N **9.3.11.2 Power Shutoff.**

N **9.3.11.2.1*** 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.

N **9.3.11.2.2** The alarm shall sound at the operator control station, and feed to the conveyor shall be stopped or diverted.

N **9.3.12 Air-Moving Devices (Fans and Blowers).**

N **9.3.12.1** Air-moving devices (AMDs) shall conform to the requirements of NFPA 91 except as amended by the requirements of this chapter.

N **9.3.12.2 Combustible Particulate Solids.**

N **9.3.12.2.1*** Where an explosion hazard exists, systems shall be designed in such a manner that combustible particulate solids do not pass through an AMD.

N **9.3.12.2.2*** The requirement of 9.3.12.2.1 shall not apply to systems designed to operate at a combustible particulate solids concentration or hybrid mixture concentration of less than 10 percent of the MEC or for a hybrid mixture, the lower of 10 percent of the MEC of the dust, or 10 percent of the LFL of the vapor.

N **9.3.12.2.3*** The requirement of 9.3.12.2.1 shall not apply to 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 9.7.1.1(1), 9.7.1.1(4), 9.7.1.1(5), or 9.7.2.1.

N **9.3.12.2.4** Where the MEC value is unknown, a value of 0.03 oz/ft^3 (30 g/m^3) shall be permitted to be assumed.

N **9.3.12.2.5*** Where an AMD is located in the dirty air stream and the dust/air stream concentration is higher than 10 percent of the MEC, fans and blowers shall be of Type A or Type B spark-resistant construction per AMCA 99, *Standards Handbook*, or Type C spark-resistant construction protected with spark detection and extinguishment located downstream of the fan.

N **9.3.12.3** Where a fire hazard exists and where combustible particulate solids pass through an AMD, provisions shall be made to prevent ignited material from entering processes downstream, in accordance with 9.8.3.

N **9.3.13 Air-Material Separators (Air Separation Devices).**

N **9.3.13.1 General.**

N **9.3.13.1.1 Location.**

N **9.3.13.1.1.1** Where an explosion hazard exists, AMSs with a dirty-side volume of 8 ft^3 (0.2 m^3) or greater shall be located outside of buildings.

N **9.3.13.1.1.2*** The requirement of 9.3.13.1.1.1 shall not apply to the following:

(1) AMSs that are protected in accordance with 9.7.1
(2) AMSs that have a dirty-side volume of less than 8 ft^3 (0.2 m^3)
(3) Wet AMSs that meet all the following criteria:
    (a) Interlocks are provided to shut down the system if the flow rate of the scrubbing medium is less than the designed minimum flow rate.
    (b) The scrubbing medium is not a flammable or combustible liquid.
    (c) The separator is designed to prevent the formation of a combustible dust cloud within the AMS.
(4)* Enclosureless AMSs meeting all the following criteria shall be permitted to be used:
    (a) The filter medium is not shaken or pressure-pulsed to dislodge dust during operation.
    (b) The AMS is not used to vent or serve metal grinders, hot work processes, or machinery that can produce sparks.
    (c) The AMS is not used to vent or serve sanders, abrasive planers, or similar sanding process equipment.
    (d)* Each collector system has a maximum air flow–handling capacity of 5000 cfm (2.4 m^3/sec).
    (e)* The fan motor is suitable for Class II, Division 2, or Class III, as appropriate.
    (f) The collected dust is removed daily or at a frequency sufficient to ensure efficient operation

and to limit the collected dust to less than 22 lb (10 kg).

(g) The collector is located at least 20 ft (6.1 m) from any means of egress or area routinely occupied by personnel.

(h)* Multiple collectors in the same room are separated from each other by at least 20 ft (6.1 m).

(i)* The minimum ignition energy (MIE) of the collected materials is greater than 500 mJ.

(j) The fan construction is spark resistant and meets the criteria in 9.3.12.2.5.

(k) The filter medium is not located within 35 ft (10.7 m) of any open flame or hot surface capable of igniting a dust cloud of the material it contains.

N **9.3.13.1.2 Protection.**

N **9.3.13.1.2.1** Where both an explosion hazard and a fire hazard exist in an AMS, protection for each type of hazard shall be provided.

N **9.3.13.1.2.2** Where an explosion hazard exists, AMSs with a dirty-side volume of 8 ft^3 (0.23 m^3) or greater shall be protected in accordance with 9.7.1.

N **9.3.13.1.2.3** Where a fire hazard exists, see 9.8.3.

N **9.3.13.1.3 Manifolding of Dust Collection Ducts.**

N **9.3.13.1.3.1** Manifolding of dust collection ducts to AMSs shall not be permitted.

N **9.3.13.1.3.2** 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.

N **9.3.13.1.3.3** 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 9.7.2.

N **9.3.13.1.3.4** Dust collection ducts for centralized vacuum cleaning systems shall be permitted to be manifolded.

N **9.3.13.1.4*** Isolation devices shall be provided for AMSs in accordance with 9.7.2.

N **9.3.13.1.5** Where lightning protection is provided, it shall be installed in accordance with NFPA 780.

N **9.3.13.1.6 Exhaust Air.**

N **9.3.13.1.6.1** Exhaust air from the final AMS shall be discharged outside to a restricted area and away from air intakes.

N **9.3.13.1.6.2** Air from AMSs shall be permitted to be recirculated directly back to the pneumatic conveying system.

N **9.3.13.1.6.3*** Recycling of AMS exhaust to buildings or rooms shall be permitted when all of the following requirements are met:

(1) Combustible or flammable gases or vapors are not present either in the intake or the recycled air in concentrations above applicable industrial hygiene exposure limits or 1 percent of the LFL, whichever is lower.

(2)* Combustible particulate solids are not present in the recycled air in concentrations above applicable industrial hygiene exposure limits or 1 percent of the MEC, whichever is lower.

(3)* The oxygen concentration of the recycled air stream is between 19.5 percent and 23.5 percent by volume.

(4) Deflagration isolation is incorporated to prevent transmission of flame and pressure effects from a deflagration in an AMS back to the facility in accordance with 9.7.2, unless a DHA indicates that those effects do not pose a threat to the facility or the occupants.

(5) Provisions are incorporated to prevent transmission of smoke and flame from a fire in an AMS back to the facility unless a DHA indicates that those effects do not pose a threat to the facility or the occupants.

(6) The system includes a method for detecting AMS malfunctions that would reduce collection efficiency and allow increases in the amount of combustible particulate solids returned to the building.

(7) The building or room to which the recycled air is returned meets the fugitive dust control and housekeeping requirements of this standard (Chapter 8).

(8) Recycled-air ducts are inspected and cleaned at least annually.

N **9.3.13.1.6.4*** A flame-arresting and particulate-retention device that is designed for use on explosion vent discharge shall not be used as an explosion isolation device in a return air line.

N **9.3.13.1.7** 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.

N **9.3.13.1.8** Operator controls for AMSs associated with pneumatic conveying, dust collection, or centralized vacuum cleaning systems shall be installed in a location that is safe from the effects of a vented deflagration in the AMS.

N **9.3.13.2 Construction.**

N **9.3.13.2.1 Noncombustible Material.**

N **9.3.13.2.1.1** AMSs shall be constructed of noncombustible materials.

N **9.3.13.2.1.2** Filter media and filter media support frames shall be permitted to be constructed of combustible material.

N **9.3.13.2.1.3** Portable containers intended to receive materials discharged from an AMS, where isolated from the AMS by a valve, shall be permitted to be constructed of combustible material.

N **9.3.13.2.2 Maximum Material Flow.**

N **9.3.13.2.2.1** AMSs shall be constructed to minimize internal ledges or other points of dust accumulation.

N **9.3.13.2.2.2** Hopper bottoms shall be sloped, and the discharge conveying system shall be designed to handle the maximum material flow attainable from the system.

N **9.3.13.2.3 Access Doors.**

N **9.3.13.2.3.1** Access doors or openings shall be provided to permit inspection, cleaning, and maintenance.

N **9.3.13.2.3.2** Access doors or openings shall be designed to prevent dust leaks.

N **9.3.13.2.3.3** Access doors shall be permitted to be used as deflagration vents if they are specifically designed for both purposes.

N **9.3.13.2.3.4** Access doors shall be bonded and grounded.

N **9.3.13.2.3.5*** Access doors not designed to be used as deflagration vents shall be designed to withstand the vented explosion pressure (P_{red}).

N **9.3.14* Size Reduction.**

N **9.3.14.1** Before material is processed by size reduction equipment, foreign materials shall be excluded or removed as required by 9.4.1.2.

N **9.3.14.2** Where an explosion hazard exists, protection shall be provided as specified in 9.7.1.

N **9.3.14.3** Where a fire hazard exists, protection shall be provided in accordance with 9.8.3.

N **9.3.15* Particle Size Separation.**

N **9.3.15.1** Particle separation devices shall be in dusttight enclosures.

N **9.3.15.2** Connection ducts shall be in conformance with 9.3.6.

N **9.3.15.3* Explosion Protection.**

N **9.3.15.3.1** Where an explosion hazard exists, protection shall be provided as specified in 9.7.1.

N **9.3.15.3.2*** Screens and sieves shall not be required to have explosion protection.

N **9.3.15.4** Where a fire hazard exists, protection shall be in accordance with 9.8.3.

N **9.3.16 Mixers and Blenders.**

N **9.3.16.1** Mixers and blenders shall be designed to control the release of dust.

N **9.3.16.2** Foreign materials shall be excluded or removed as required by 9.4.1.2.

N **9.3.16.3** Where an explosion hazard exists, protection shall be provided as specified in 9.7.1.

N **9.3.16.4** Where a fire hazard exists, protection shall be in accordance with 9.8.3.

N **9.3.16.5** 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.

N **9.3.17* Dryers.**

N **9.3.17.1** Heating systems shall be in accordance with 9.4.6.

N **9.3.17.2 Drying Media.**

N **9.3.17.2.1** Drying media that come into contact with material being processed shall not be recycled to rooms or buildings.

N **9.3.17.2.2** 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.

N **9.3.17.3** Dryers shall be constructed of noncombustible materials.

N **9.3.17.4** Interior surfaces of dryers shall be designed so that accumulations of material are minimized and cleaning is facilitated.

N **9.3.17.5** 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.

N **9.3.17.6** Where an explosion hazard exists, protection shall be provided as specified in 9.7.1.

N **9.3.17.7** Where a fire hazard exists, protection shall be in accordance with 9.8.3.

N **9.3.17.8** Heated dryers shall comply with NFPA 86.

N **9.3.17.9*** Heated dryers shall have operating controls arranged to maintain the temperature of the drying chamber within the prescribed limits.

N **9.3.17.10** 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

N **9.3.18 Ultrafine Particles.**

N **9.3.18.1* General.** The processing, handling, and storage of ultrafine particles shall also follow the requirements of this section.

N **9.3.18.2** If testing of a mixture or particle size distribution that includes ultrafine particles shows that the explosibility characteristics are similar to the micrometer particles the requirements of this section shall not apply.

N **9.3.18.3*** The DHA performed for processes or facilities that handle ultrafine particles shall include an assessment of the hazards associated with the difficulty of containing and controlling ultrafine particles in the equipment and processes involved in addition to the fire and deflagration hazards customarily addressed.

N **9.3.18.4** The DHA shall include a determination of the appropriate effective fire and explosion protection measures for combustible ultrafine particle processes and equipment.

N **9.3.18.5 Ultrafine Particle Production Processes.**

N **9.3.18.5.1*** Fire, flash-fire, and explosion hazards associated with production of ultrafine particles shall be assessed and documented.

N **9.3.18.5.2** Any process that involves metal ultrafine particles shall refer to NFPA 484.

N **9.3.18.6 Housekeeping.**

N **9.3.18.6.1** A documented housekeeping program shall be established based on the hazards described in the DHA for all ultrafine particles and shall include special provisions for preventing personnel exposure to ultrafine particles during the cleaning process.

N **9.3.18.6.2** Personal protective equipment (PPE) provided for personnel during the cleaning process shall consider the hazards associated with the ultrafine particles involved.

N **9.3.19 Additive Manufacturing.**

N **9.3.19.1 General Requirements.**

N **9.3.19.1.1** Additive manufacturing shall comply with the additional requirements of this section.

N **9.3.19.1.2** Additive manufacturing involving metal powders shall be covered by NFPA 484.

N **9.3.19.1.3** Verification of the grounding and bonding of portable equipment shall be done before each use.

N **9.3.19.1.4** Containers used for conductive particulate solids shall be conductive or static dissipative.

N **9.3.19.1.4.1** Conductive and static-dissipative powder containers shall be bonded to the equipment prior to the transfer of powder to and from such equipment.

N **9.3.19.1.5** Control measures shall be provided to avoid the creation of suspended dust clouds during transfer of powder to and from equipment.

N **9.3.19.1.6** Portable vacuum cleaning units and portable dust collection equipment shall be listed for use in a Class II atmosphere.

N **9.4 Ignition Source Control.**

N **9.4.1 Heat from Mechanical Sparks and Friction.**

N **9.4.1.1 Risk Assessment.** A documented risk assessment acceptable to the AHJ shall be permitted to be conducted to determine the level of protection to be provided according to this chapter.

N **9.4.1.2 Foreign Materials.**

N **9.4.1.2.1** Means shall be provided to prevent foreign material from entering the system when such foreign material presents an ignition hazard.

N **9.4.1.2.2** Floor sweepings shall not be returned to any machine.

N **9.4.1.2.3*** 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

N **9.4.1.3* Inherently Ignitible Process Streams.**

N **9.4.1.3.1** Where the process is configured such that the pneumatic conveying, dust collection, or centralized vacuum cleaning system conveys materials that can act as an ignition source, means shall be provided to minimize the hazard.

N **9.4.1.3.2** The means used to minimize the ignition source hazard specified in 9.4.1.3.1 shall be permitted to include protection measures identified in 9.3.1.3 and 9.8.3.1, as appropriate.

N **9.4.1.4* Belt Drives.** Belt drives shall be designed to stall without belt slippage, or a safety device shall be provided to shut down the equipment if slippage occurs.

N **9.4.1.5* Bearings.**

N **9.4.1.5.1** Roller or ball bearings shall be used on all processing and transfer equipment.

N **9.4.1.5.2** Bushings shall be permitted to be used when a documented engineering evaluation shows that mechanical loads and speeds preclude ignition due to frictional heating.

N **9.4.1.5.3** Lubrication shall be performed in accordance with the manufacturer's recommendations.

N **9.4.1.5.4*** Bearings that are directly exposed to a combustible dust atmosphere or that are subject to dust accumulation, either of which poses a dust ignition hazard, shall be monitored for overheating. [**652:**9.4.5.2]

N **9.4.1.5.5** The owner/operator shall establish frequencies for monitoring bearings in 9.4.1.5.4. [**652:**9.4.5.3]

N **9.4.1.5.6*** It shall be permitted to eliminate bearing monitoring based on a risk assessment acceptable to the AHJ. [**652:**9.4.5.4]

N **9.4.1.6 Equipment.** Equipment with moving parts shall be installed and maintained so that true alignment is maintained and clearance is provided to minimize friction.

N **9.4.2 Electrical Equipment.**

N **9.4.2.1** All electrical equipment and installations shall comply with the requirements of *NFPA 70*.

N **9.4.2.2*** 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*, as applicable.

N **9.4.2.3** Hazardous (classified) areas that are identified in accordance with 9.4.2.2 shall be documented, and such documentation shall be permanently maintained on file for the life of the facility.

N **9.4.3* Electrostatic Discharges.** The requirements of 9.4.3.2 through 9.4.3.6 shall be applied retroactively.

N **9.4.3.1** For electrostatic hazard assessment purposes, MIE determination of dust clouds shall be based on a purely capacitive discharge circuit in accordance with ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.

N **9.4.3.2* Conductive Components.**

N **9.4.3.2.1*** All system components shall be conductive.

N **9.4.3.2.2** Nonconductive system components shall be permitted where all of the following conditions are met:

(1)* Hybrid mixtures and flammable gas/vapor atmospheres are not present.
(2)* Conductive particulate solids are not handled.
(3)* The nonconductive components do not result in isolation of conductive components from ground.
(4)* The breakdown strength across nonconductive sheets, coatings, membranes, or pipe/vessel wall with thickness less than 8 mm does not exceed 4 kV, and the breakdown strength across nonconductive woven materials does not

exceed 6 kV, when used in high surface charging processes (e.g., pneumatic conveying, milling).

N **9.4.3.2.3*** Bonding and grounding with a resistance of less than 1.0×10^6 ohms to ground shall be provided for conductive components. [**652:**9.4.7.1.3]

N **9.4.3.3*** Where belt drives are used in areas where combustible dust clouds or ignitible vapor or gas atmospheres might be present, the belts shall have a resistance of less than 1.0×10^6 ohms to ground.

N **9.4.3.4*** Where flexible hose is used to connect conductive components, the resistance between the conductive components shall be less than 1×10^6 ohms.

N **9.4.3.5* Flexible Connectors.**

N **9.4.3.5.1* Retroactivity.** This section shall not be required to be applied retroactively. [**652:**9.4.7.1.4.1]

N **9.4.3.5.2** Flexible connectors longer than 6.6 ft (2 m) shall have an end-to-end resistance of less than 1.0×10^8 ohms to ground even where an internal or external bonding wire connects the equipment to which the flexible connector is attached. [**652:**9.4.7.1.4.2]

N **9.4.3.5.3*** Where flammable vapors are not present, flexible connectors with a resistance equal to or greater than 1.0×10^8 ohms shall be permitted under either of the following conditions:

(1) The dust has an MIE greater than 2000 mJ.
(2) The maximum powder transfer velocity is less than 2000 fpm (10 m/sec).

[**652:**9.4.7.1.4.3]

N **9.4.3.6* Flexible Intermediate Bulk Containers (FIBCs).** FIBCs shall be permitted to be used for the handling and storage of combustible particulate solids in accordance with the requirements in 9.4.3.6.1 through 9.4.3.6.7. [**652:**9.4.7.4]

N **9.4.3.6.1*** Electrostatic ignition hazards associated with the particulate and objects surrounding or inside the FIBC shall be included in the DHA required by Section 7.1. [**652:**9.4.7.4.1]

N **9.4.3.6.2*** Type A FIBCs shall be limited to use with noncombustible particulate solids or combustible particulate solids having an MIE greater than 1000 mJ. [**652:**9.4.7.4.2]

N **9.4.3.6.2.1** Type A FIBCs shall not be used in locations where flammable vapors are present. [**652:**9.4.7.4.2.1]

N **9.4.3.6.2.2** Type A FIBCs shall not be used with conductive dusts. [**652:**9.4.7.4.2.2]

N **9.4.3.6.3*** Type B FIBCs shall be permitted to be used where combustible dusts having an MIE greater than 3 mJ are present. [**652:**9.4.7.4.3]

N **9.4.3.6.3.1** Type B FIBCs shall not be used in locations where flammable vapors are present. [**652:**9.4.7.4.3.1]

N **9.4.3.6.3.2** Type B FIBCs shall not be used for conductive dusts. *(See 3.3.10.1.)* [**652:**9.4.7.4.3.2]

N **9.4.3.6.4*** Type C FIBCs shall be permitted to be used with combustible particulate solids and in locations where Class I Group C/D or Zone Group IIA/IIB flammable vapors or gases, as defined by *NFPA 70*, are present.

N **9.4.3.6.4.1** Conductive FIBC elements shall terminate in a grounding tab, and resistance from these elements to the tab shall be less than or equal to 10^7 ohms. [**652:**9.4.7.4.4.1]

N **9.4.3.6.4.2** Type C FIBCs shall be grounded during filling and emptying operations with a resistance to ground of less than 25 ohms. [**652:**9.4.7.4.4.2]

N **9.4.3.6.4.3** Type C FIBCs shall be permitted to be used for conductive dusts where a means for grounding the conductive dusts is present. [**652:**9.4.7.4.4.3]

N **9.4.3.6.5*** Type D FIBCs shall be permitted to be used with combustible particulate solids and in locations where Class I Group C/D or Zone Group IIA/IIB flammable vapors or gases, as defined by *NFPA 70*, having an MIE greater than 0.14 mJ are present.

N **9.4.3.6.5.1*** Type D FIBCs shall not be permitted to be used for conductive particulate solids. [**652:**9.4.7.4.5.1]

N **9.4.3.6.6*** Type B, Type C, and Type D FIBCs shall be tested and verified as safe for their intended use by a recognized testing organization in accordance with the requirements and test procedures specified in IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, before being used in hazardous environments. [**652:**9.4.7.4.6]

N **9.4.3.6.6.1** Intended use shall include both the product being handled and the environment in which the FIBC will be used. [**652:**9.4.7.4.6.1]

N **9.4.3.6.6.2** Materials used to construct inner baffles, other than mesh or net baffles, shall meet the requirements for the bag type in which they are to be used. [**652:**9.4.7.4.6.2]

N **9.4.3.6.6.3*** Inner liners shall be suitable to maintain the electrostatic characteristics of the bag types in which they are used.

N **9.4.3.6.6.4** Documentation of test results shall be made available to the AHJ. [**652:**9.4.7.4.6.3]

N **9.4.3.6.6.5** FIBCs that have not been tested and verified for type in accordance with IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, shall not be used for combustible dusts or in flammable vapor atmospheres. [**652:**9.4.7.4.6.4]

N **9.4.3.6.7*** Deviations from the requirements in 9.4.3.6.1 through 9.4.3.6.6 for safe use of FIBCs shall be permitted based on a documented risk assessment acceptable to the AHJ. [**652:**9.4.7.4.7]

N **9.4.3.7 Rigid Intermediate Bulk Containers (RIBCs).**

N **9.4.3.7.1*** Conductive RIBCs shall be permitted to be used for dispensing into any flammable vapor, gas, dust, or hybrid atmospheres provided that the RIBCs are electrically grounded. [**652:**9.4.7.4.5.1]

N **9.4.3.7.2*** Nonconductive RIBCs shall not be permitted to be used for applications, processes, or operations involving combustible particulate solids or where flammable vapors or gases are present unless a documented risk assessment assessing the electrostatic hazards is acceptable to the AHJ. [**652:**9.4.7.5.2]

N **9.4.3.8** 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.

N **9.4.3.9*** Manual additions of solids through an open port or a manway into a vessel containing flammable atmospheres shall be permitted to be done in 50 lb (25 kg) batches or smaller, provided the requirements of 9.4.3.9.1 through 9.4.3.9.7 are satisfied.

N **9.4.3.9.1*** Conductive or static-dissipative components of the container shall be grounded.

N **9.4.3.9.2** Direct emptying of powders from nonconductive plastic bags into a vessel that contains a flammable atmosphere shall be strictly prohibited.

N **9.4.3.9.3** The use of nonconductive liners in grounded conductive or static-dissipative outer packaging shall be permitted, provided that the liner thickness is less than 0.08 in. (2 mm) and the liner cannot become detached during emptying.

N **9.4.3.9.4*** Loading chutes, receiving vessels, and auxiliary devices used for addition of bulk material shall be conductive and grounded.

N **9.4.3.9.5*** Personnel in the vicinity of openings of vessels that contain flammable atmospheres shall be grounded.

N **9.4.3.9.6** Operators shall wear flame-resistant garments as specified in NFPA 2113 and any other personal protective equipment (PPE) required for protection against flash-fire hazards during charging operations.

N **9.4.3.9.7*** A documented risk assessment acceptable to the AHJ shall be conducted to determine additional engineering and administrative controls necessary to protect against ignition of the flammable atmosphere.

N **9.4.3.10* Grounding of Personnel.**

N **9.4.3.10.1*** Where an explosive atmosphere exists and is subject to ignition from an electrostatic spark discharge from ungrounded personnel, personnel involved in manually filling or emptying particulate containers or vessels shall be grounded during such operations. [**652:**9.4.7.3.1]

N **9.4.3.10.2** Personnel grounding shall not be required where both of the following conditions are met:

(1) Flammable gases, vapors, and hybrid mixtures are not present.
(2)* The minimum ignition energy of the dust cloud is greater than 30 mJ.

[**652:**9.4.7.3.2]

N **9.4.4 Cartridge-Actuated Tools.** The requirements of 9.4.4.1 through 9.4.4.3 shall be applied retroactively.

N **9.4.4.1** 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.

N **9.4.4.2** Accepted lockout/tagout procedures shall be followed for the shutdown of machinery.

N **9.4.4.3** The use of cartridge-actuated tools shall be in accordance with 8.5.2.

N **9.4.4.4** 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.

N **9.4.5 Hot Work.** Hot work shall be managed in accordance with Section 8.5.

N **9.4.6 Process and Comfort Heating Systems.**

N **9.4.6.1*** In areas processing combustible dust, process and comfort heating shall be provided by indirect means.

N **9.4.6.2** Fired equipment shall be located outdoors or in a separate dust-free room or building.

N **9.4.6.3** Air for combustion shall be taken from a clean outside source.

N **9.4.6.4** Comfort air systems for processing areas containing combustible dust shall not be recirculated.

N **9.4.6.5** 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.

N **9.4.6.6** Comfort air shall not be permitted to flow from hazardous to nonhazardous areas.

N **9.4.7* Hot Surfaces.** In areas where a dust explosion hazard or dust flash-fire hazard exists, the temperature of external surfaces, such as compressors; steam, water, or process piping; ducts; and process equipment shall be maintained below 80 percent (in degrees Celsius) of the lower of the dust surface ignition temperature or the dust-cloud ignition temperature.

N **9.4.8 Industrial Trucks.**

N **9.4.8.1** Where used, industrial trucks shall be listed or approved for the electrical classification of the area, as determined by 9.4.2, and shall be used in accordance with NFPA 505.

N **9.4.8.2*** Where industrial trucks, in accordance with NFPA 505 are not commercially available, a documented risk assessment acceptable to the AHJ shall be permitted to be used to specify the fire and explosion prevention features for the equipment used.

N **9.4.9 Other Vehicles.** Risk management controls shall be implemented to ensure the safe operation of vehicles not covered under NFPA 505, which could introduce ignition sources into classified areas. Such risk management controls include the application of hot work controls under NFPA 51B.

N **9.5 Pyrophoric Dusts. (Reserved)**

N **9.6 Dust Control.**

N **9.6.1** Continuous suction to minimize the escape of dust shall be provided for processes where combustible dust is liberated in normal operation.

N **9.6.2** The dust shall be conveyed to AMSs.

N **9.6.3** Housekeeping procedures shall be in accordance with Section 8.4.

N **9.6.4** Dust collection and centralized vacuum systems shall be designed in accordance with 9.3.3.2.

N **9.7 Explosion Prevention and Protection.**

N **9.7.1 Explosion Protection for Equipment.**

N **9.7.1.1** 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
   (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 in accordance with NFPA 68
(3) Deflagration pressure containment in accordance with NFPA 69
(4) Deflagration suppression systems in accordance with NFPA 69
(5)* Dilution with a noncombustible dust to render the mixture noncombustible *(See 9.7.1.2.)*
(6)* Deflagration venting through a listed dust retention and flame-arresting device

N **9.7.1.2** If the method in 9.7.1.1(5) is used, test data for specific dust and diluent combinations shall be provided and shall be acceptable to the AHJ.

N **9.7.2* Isolation of Equipment and Work Areas.**

N **9.7.2.1*** Where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between connected equipment and/or work areas in accordance with NFPA 69.

N **9.7.2.2** Isolation devices shall not be required where oxidant concentration has been reduced or where the dust has been rendered noncombustible in accordance with 9.7.1.1(1) or 9.7.1.1(5).

N **9.8 Fire Protection.**

N **9.8.1 Fire Protection for Equipment.** Equipment fire protection shall be designed in accordance with 9.8.3.

N **9.8.2 Fire Protection for Facility.** Where a fire propagation hazard exists, the requirements of 9.8.3 shall apply.

N **9.8.3 Fire Protection.**

N **9.8.3.1 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.

N **9.8.3.2 System Requirements.** Fire protection systems required by this standard shall comply with 9.8.3.2.1 through 9.8.3.2.10.3.

N **9.8.3.2.1*** Fire-extinguishing agents shall be compatible with the conveyed materials.

N **9.8.3.2.2** Where fire detection systems are incorporated into pneumatic conveying, dust collection, or centralized vacuum cleaning systems, an analysis shall be conducted to identify safe interlocking requirements for AMDs and process operations.

N **9.8.3.2.3** Where fire-fighting water or wet product can accumulate in the system, vessel and pipe supports shall be designed to support the additional water weight.

N **9.8.3.2.4 Detection Systems.**

N **9.8.3.2.4.1** Where fire detection systems are incorporated into the pneumatic conveying, dust collection, or centralized vacuum cleaning system, the fire detection systems shall be interlocked to shut down any active device feeding materials to the pneumatic conveying, dust collection, or centralized vacuum cleaning system, on actuation of the detection system.

N **9.8.3.2.4.2** Where spark or infrared detection and extinguishing systems are provided, the process shall be permitted to continue operating on activation of the detection system.

N **9.8.3.2.4.3** 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.

N **9.8.3.2.5** Where the actuation of fire-extinguishing systems is achieved by means of electronic fire detection, the fire detection system, including control panels, detectors, and notification appliances, shall be designed, installed, and maintained in accordance with *NFPA 72*.

N **9.8.3.2.6** All fire detection initiating devices shall be connected to the fire detection control panel via Class A or B circuits as described in *NFPA 72*.

N **9.8.3.2.7** All fire detection notification appliances shall be connected to the fire detection control panel via Class A or B circuits as described in *NFPA 72*.

N **9.8.3.2.8 System Releasing Devices.**

N **9.8.3.2.8.1** All fire-extinguishing system releasing devices, solenoids, or actuators shall be connected to the fire detection control panel via Class A or B circuits as described in *NFPA 72*.

N **9.8.3.2.8.2** The supervision shall include the continuity of the extinguishing system releasing device, whether that device is a solenoid coil, a detonator (explosive device) filament, or other such device.

N **9.8.3.2.9** All supervisory devices that monitor critical elements or functions in the fire detection and extinguishing system shall be connected to the fire detection control panel via Class A or B circuits as described in *NFPA 72*.

N **9.8.3.2.10* Abort Gates/Abort Dampers.**

N **9.8.3.2.10.1 Construction.**

N **(A)** Abort gates and abort dampers shall be constructed of noncombustible materials.

N **(B)** Abort gates shall be actuated by spark detection in the duct or pipe upstream of the device.

N **(C)*** The detection system and abort gate shall respond to prevent sparks, glowing embers, or burning materials from passing beyond the abort gate.

N **9.8.3.2.10.2 Operation.**

N **(A)** 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.

N **(B)*** An abort gate or abort damper shall be provided with a manually activated reset located proximate to the device such that, subsequent to operation, it can be returned to the normal operating position only at the damper (gate).

N **(C)** Automatic or remote reset provisions shall not be permitted.

N **9.8.3.2.10.3 Fire Protection.**

N **(A)** All fire protection abort gates or abort dampers shall be connected to the fire detection control panel via Class A or D circuits as described in *NFPA 72.*

N **(B)** When the abort gate is connected via a Class A circuit, 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.

N **9.8.3.3 Fire Extinguishers.**

N **9.8.3.3.1** Portable fire extinguishers shall be provided throughout all buildings in accordance with the requirements of NFPA 10.

N **9.8.3.3.2*** Personnel shall be trained to use portable fire extinguishers in a manner that minimizes the generation of dust clouds during discharge.

N **9.8.3.4 Hose, Standpipes, and Hydrants.**

N **9.8.3.4.1** Standpipes and hose, where provided, shall comply with NFPA 14.

N **9.8.3.4.2 Nozzles.**

N **9.8.3.4.2.1*** 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.

N **9.8.3.4.2.2*** Straight-stream nozzles shall not be used on fires in areas where dust clouds can be generated.

N **9.8.3.4.2.3** Straight-stream nozzles or combination nozzles shall be permitted to be used to reach fires in locations that are otherwise inaccessible with the nozzles specified in 9.8.3.4.2.1.

N **9.8.3.4.3** Private outside protection, including outside hydrants and hoses, where provided, shall comply with NFPA 13.

N **9.8.3.5* Automatic Sprinklers.**

N **9.8.3.5.1*** Where a process that handles combustible particulate solids uses flammable or combustible liquids, a documented risk assessment that is acceptable to the AHJ shall be used to determine the need for automatic sprinkler protection in the enclosure in which the process is located.

N **9.8.3.5.2** Automatic sprinklers, where provided, shall be installed in accordance with NFPA 13.

N **9.8.3.5.3** 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.

N **9.8.3.6 Spark/Ember Detection and Extinguishing Systems.** Spark/ember detection and extinguishing systems shall be designed, installed, and maintained in accordance with NFPA 69 and *NFPA 72.*

N **9.8.3.7 Special Fire Protection Systems.**

N **9.8.3.7.1** 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
(2) NFPA 12
(3) NFPA 12A
(4) NFPA 15
(5) NFPA 16
(6) NFPA 17
(7) NFPA 25
(8) NFPA 750
(9) NFPA 2001

N **9.8.3.7.2** The extinguishing systems shall be designed and used in a manner that minimizes the generation of dust clouds during their discharge.

N **9.8.3.8 Fire Alarm Service.** Fire alarm service, if provided, shall comply with *NFPA 72.*

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

N **A.1.1.1** The scope statement uses the term *combustible dust* as it is defined in this document. In this definition, there is no upper limit for particle size for combustible dusts and no exclusion on nonspherical particles such as flakes, platelets, and fibers. The current edition of *NFPA 70 (NEC)* defines combustible dust in a more restrictive manner, focused on the necessary electrical equipment design requirements and limited to a maximum particle size of 500 microns. *NFPA 70* further excludes fibrous materials and flyings from its combustible dust definition. While a material might not be a combustible dust per the *NFPA 70* definition, it can present the same process and operational hazards as materials with fine particles. [**652:**A.1.1]

A.1.6 This standard is usually enforced under authorities established by state law. Under the state building code, the edition of the standard adopted by the state at the time of construction is applicable.

Under federal law, the enforcement organization is usually the Occupational Safety and Health Administration (OSHA). Under section 5 (a)(1) of the OSH Act, the current edition of a standard is typically referenced during an enforcement action.

For existing facilities, it is often impractical to retroactively apply new engineering controls upon issuance of a new standard. Where this is the case and the retroactivity clause allows an exemption from the standard's requirements, the facility owner should refer to the version of the standard that was in effect at the time the facility was constructed or at the time of the most recent major renovation. However, recognizing that the current revision might correct deficiencies in prior editions, facility owners should review the risk associated with the facility and determine whether alternative means of protection are necessary to meet their risk tolerance and satisfy the AHJs.

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.

N **A.3.3.2 Additive Manufacturing.** Additive manufacturing is sometimes referred to as 3D printing; however, this is only one part of the process.

A.3.3.3 Air-Material Separator (AMS). Examples include the following:

(1) Cyclonic separator (cyclone) — a device utilizing centrifugal forces and geometry to separate the conveying air/gas from the majority of the conveyed material. The efficiency of this separation is based upon many factors, such as the geometry of the cyclone, material particle size and density, and air/gas mass flow. Generally, this unit is considered only an initial or primary separator, and additional separation devices are applied to meet air pollution control requirements.
(2) Dust collector — a device utilizing filter media to separate fine dust particles from the conveying air/gas stream. Dust collectors often have automatic methods for continuous filter cleaning in order to maintain the operational efficiency of the device. Typically the filter media is either cartridges or bags. The operating pressure of this device is usually limited by its shape and physical construction.
(3) Filter receiver — similar to a dust collector but designed for higher differential pressure applications.
(4) Scrubber — a device utilizing geometry, physical barriers, and/or absorption methods, along with a fluid (e.g., sprays and streams) to separate and collect gases and/or dusts.
(5) Electrostatic precipitator — a device that utilizes differences in electrical charges to remove fine particulates from the air stream.
(6) Final filter — a high-efficiency device commonly utilizing a pre-filter and a secondary filter within an enclosure to provide the last particulate removal step before the air is discharged from the system. Final filters are commonly used when the air stream is recirculated to occupied areas. This device can provide protection against the failure of a dust collector or filter receiver upstream of the device. A high efficiency particulate air (HEPA) filter is an example.

A.3.3.4 Air-Moving Device (AMD). An air-moving device is a fan or blower. A general description of each follows:

(1) Fans
    (a) A wide range of devices that utilize an impeller, contained within a housing, that when rotated create air/gas flow by negative (vacuum) or positive differential pressure.
    (b) These devices are commonly used to create comparatively high air/gas volume flows at relatively low differential pressures.
    (c) These devices are typically used with ventilation and/or dust collection systems.
    (d) Examples are centrifugal fans, industrial fans, mixed or axial flow fans, and inline fans.
(2) Blowers
    (a) A wide range of devices that utilize various-shaped rotating configurations, contained within a housing, that when rotated create air/gas flow by negative (vacuum) or positive differential pressure.
    (b) These devices are commonly used to create comparatively high differential pressures at comparatively low air/gas flows.
    (c) The most common use of these devices are with pneumatic transfer, high-velocity, low volume (HVLV) dust collection, and vacuum cleaning systems.
    (d) Examples are positive displacement (PD) blowers, screw compressors, multi-stage centrifugal compressors/blowers and regenerative blowers.

[**652,** 2019]

A.3.3.6 Centralized Vacuum Cleaning System. This system normally consists of multiple hose connection stations hard-piped to an AMS located out of the hazardous area. Positive displacement or centrifugal AMDs can be used to provide the negative pressure air flow. The hoses and vacuum cleaning tools utilized with the system should be designed to be conductive or static-dissipative in order to minimize any risk of generating an ignition source. Low MIE materials should be given special consideration in the system design and use. A primary and secondary AMS separator combination (e.g., cyclone and filter receiver) can be used if large quantities of materials are involved. However, most filter receivers are capable of handling the high material loadings without the use of a cyclone. [**652,** 2019]

A.3.3.7 Combustible Dust. Dusts traditionally were defined as material 420 μm or smaller (i.e., capable of passing through a U.S. No. 40 standard sieve). For consistency with other standards, 500 μm (i.e., capable of passing through a U.S. No. 35 standard sieve) is now considered an appropriate size criterion. Particle surface area-to-volume ratio is a key factor in determining the rate of combustion. Combustible particulate solids with a minimum dimension more than 500 μm generally have a surface-to-volume ratio that is too small to pose a deflagration hazard. Flat platelet-shaped particles, flakes, or fibers with lengths that are large compared to their diameter usually do not pass through a 500 μm sieve, yet could still pose a deflagration hazard. 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. Therefore, it can be inferred that any particulate that has a minimum dimension less than or equal to 500 μm could behave as a combustible dust if suspended in air or the process specific oxidizer. If the minimum dimension of the particulate is greater than 500 μm, it is unlikely that the material would be a combustible dust, as determined by test. The determination of whether a sample of combustible material presents a flash-fire or explosion hazard could be based on a screening test methodology such as provided in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds.* Alternatively, and a standardized test method such as ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, could be used to determine dust explosibility. Chapter 5 of NFPA 652 has additional information on testing requirements. [**652,** 2019]

There is some possibility that a sample will result in a false positive in the 20 L sphere when tested by the ASTM E1226 screening test or the ASTM E1515 test. This is due to the high energy ignition source overdriving the test. When the lowest ignition energy allowed by either method still results in a positive result, the owner/operator can elect to determine whether the sample is a combustible dust with screening tests performed in a larger scale (=1 m^3) enclosure, which is less susceptible to overdriving and thus will provide more realistic results. [**652,** 2019]

This possibility for false positives has been known for quite some time and is attributed to “overdriven” conditions that exist in the 20 L chamber due to the use of strong pyrotechnic igniters. For that reason, the reference method for explosibility testing is based on a 1 m^3 chamber, and the 20 L chamber test method is calibrated to produce results comparable to those from the 1 m^3 chamber for most dusts. In fact, the U.S. standard for 20 L testing (ASTM E1226) states, “The objective of this test method is to develop data that can be correlated to those from the 1 m^3 chamber (described in ISO 6184-1 and VDI 3673)…” ASTM E1226 further states, “Because a number of factors (concentration, uniformity of dispersion, turbulence of ignition, sample age, etc.) can affect the test results, the test vessel to be used for routine work must be standardized using dust samples whose K_{St} and P_{max} parameters are known in the 1 m^3 chamber.” [**652,** 2019]

NFPA 68 also recognizes this problem and addresses it stating that “the 20 L test apparatus is designed to simulate results of the 1 m^3 chamber; however, the igniter discharge makes it problematic to determine K_{St} values less than 50 bar-m/sec. Where the material is expected to yield K_{St} values less than 50 bar-m/sec, testing in a 1 m^3 chamber might yield lower values.” [**652,** 2019]

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. [**652,** 2019]

A dust deflagration has the following four requirements:

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

[**652,** 2019]

If the deflagration is confined and produces a pressure sufficient to rupture the confining enclosure, the event is, by definition, an “explosion.” [**652,** 2019]

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) MEC
(2) 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 E1226, *Standard Test Method for Explosibility of Dust Clouds*
(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

[**652,** 2019]

It is important to keep in mind that as a particulate is processed, handled, or transported, the particle size generally decreases due to particle attrition. Therefore, it is often necessary to evaluate the explosibility of the particulate at multiple points along the process. Where process conditions dictate the use of oxidizing media other than air, which is nominally taken as 21 percent oxygen and 79 percent nitrogen, the applicable tests should be conducted in the appropriate process-specific medium. [**652,** 2019]

A.3.3.8 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. [**652,** 2019]

The terms *particulate solid, dust,* and *fines* are interrelated. It is important to recognize that while these terms refer to various size thresholds or ranges, most particulate solids are composed of a range of particle sizes making comparison to a size threshold difficult. For example, a bulk material that is classified as a particulate solid could contain a significant fraction of dust as part of the particle size distribution. [**652,** 2019]

While hazards of bulk material are addressed in this document using the provisions related to particulate solids, it might be necessary to apply the portions of the document relating to dust where there is potential for segregation of the material and accumulation of only the fraction of the material that fits the definition of dust. Furthermore, it is difficult to establish a fractional cutoff for the size threshold, such as 10 percent below the threshold size or median particle size below the threshold size, as the behavior of the material depends on many factors including the nature of the process, the dispersibility of the dust, and the shape of the particles. [**652,** 2019]

For the purposes of this document, the term *particulate solid* does not include an upper size limitation. This is intended to encompass all materials handled as particulates, including golf balls, pellets, wood chunks and chips, etc. [**652,** 2019]

The term *particulate solid* is intended to include those materials that are typically processed using bulk material handling techniques such as silo storage, pneumatic or mechanical transfer, etc. While particulate solids can present a fire hazard, they are unlikely to present a dust deflagration hazard unless they contain a significant fraction of dust, which can segregate and accumulate within the process or facility. [**652,** 2019]

Dusts traditionally were defined as material 420 μm or smaller (capable of passing through a U.S. No. 40 standard sieve). For consistency with other standards, 500 μm (capable of passing through a U.S. No. 35 standard sieve) is now considered an appropriate size criterion. Particle surface area-to-volume ratio is a key factor in determining the rate of combustion. Combustible particulate solids with a minimum dimension more than 500 μm generally have a surface-to-volume ratio that is too small to pose a deflagration hazard. Flat platelet-shaped particles, flakes, or fibers with lengths that are large compared to their diameters usually do not pass through a 500 μm sieve, yet could still pose a deflagration hazard. Many particulates accumulate electrostatic charges 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 particulate that has a minimum dimension less than or equal to 500 μm could behave as a combustible dust if suspended in air or in the process specific oxidizer. If the minimum dimension of the particulate is greater than 500 μm, it is unlikely that the material would be a combustible dust, as determined by test. [**652,** 2019]

Typically, the term *fines* refers to the fraction of material that is below 75 μm or that will pass through a 200-mesh sieve. Alternatively, fines can be characterized as the material collected from the final dust collector in a process or the material collected from the highest overhead surfaces in a facility. Fines typically represent a greater deflagration hazard than typical dusts of the same composition because they are more likely to remain suspended for an extended period of time and to have more severe explosion properties (higher K_{St}, lower MIE, etc.). [**652,** 2019]

N **A.3.3.10 Conductive.** A typical threshold for solid materials of construction would be a volume resistivity less than 10^5 ohm-m. [**652,** 2019]

A.3.3.11 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.

Δ **A.3.3.12.1 Dust Explosion Hazard Area.** See NFPA 68 for evaluating strength of enclosures.

A.3.3.12.2 Dust Flash-Fire Hazard Area. Where the dust cloud concentration is equal to or greater than the MEC, it poses a dust explosion and dust flash-fire hazard. A propagating deflagration yields a flash fire through the hazard area. In *Dust Explosions in the Process Industries*, Eckhoff observes for coal dust that if the cloud obscures a 25 W lightbulb over a 6.6 ft (2 m) length, the concentration is probably close to the MEC. It is customary to consider a dust cloud hazardous when the concentration exceeds 25 percent of the MEC. It is recognized that it is often very difficult or impractical to measure airborne dust concentration in this range in an industrial setting. For this reason, it is often necessary to rely on subjective measures to determine the dust cloud concentration.

N **A.3.3.14 Dissipative.** Typically, a dissipative material is one having a surface resistivity between 10^5 ohms per square and 10^9 ohms per square or a volume resistivity between 10^5 ohm-m and 10^9 ohm-m. The intent is to limit the voltage achieved by electrostatic charge accumulation to a potential that is less than the threshold voltage for incendive discharge. Some applications might require different resistivities to accommodate different charging rates or desired relaxation times. [**652,** 2019]

A.3.3.17 Dust Collection System. A typical dust collection system consists of the following:

(1) Hoods — devices designed to contain, capture, and control the airborne dusts by using an induced air flow in close proximity to the point of dust generation (local exhaust zone) to entrain fugitive airborne dusts.
(2) Ducting — piping, tubing, fabricated duct, etc., used to provide the controlled pathway from the hoods to the dust collector (AMS). Maintaining adequate duct velocity (usually 4000 fpm or higher) is a key factor in the proper functioning of the system.
(3) Dust collector — an AMS designed to filter the conveyed dusts from the conveying air stream. Usually these devices

have automatic methods for cleaning the filter media to allow extended use without blinding. In some systems, a scrubber or similar device is used in place of the filter unit.

(4) Fan package — an AMD designed to induce the air flow through the entire system.

The system is designed to collect only suspended dusts at the point of generation and not dusts at rest on surfaces. The system is also not designed to convey large amounts of dusts as the system design does not include friction loss due to solids loading in the pressure drop calculation. Thus, material loading must be minimal compared to the volume or mass of air flow.

A.3.3.20 Dust Hazards Analysis (DHA). In the context of this definition, it is not intended that the dust hazards analysis (DHA) must comply with the process hazards analysis (PHA) requirements contained in OSHA regulation 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals." While the DHA can comply with OSHA PHA requirements, other methods can also be used. *(See Annex B of NFPA 652).* However, some processes might fall within the scope of OSHA regulation 29 CFR 1910.119, and there could be a legal requirement to comply with that regulation. [**652,** 2019]

A.3.3.24 Flash Fire. A flash fire requires an ignition source and a hydrocarbon, or an atmosphere containing combustible, finely divided particles (e.g., coal dust or grain) having a concentration greater than the lower explosive limit of the chemical. Both hydrocarbon and dust flash fires generate temperatures from 1000°F to 1900°F (538°C to 1038°C). The intensity of a flash fire depends on the size of the gas, vapor, or dust cloud. When ignited, the flame front expands outward in the form of a fireball. The resulting effect of the fireball's energy with respect to radiant heat significantly enlarges the hazard areas around the point of ignition.

A.3.3.28 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. 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.3.3.29.1 Flexible Intermediate Bulk Container (FIBC). FIBCs are usually made from nonconductive materials. Electrostatic charges that develop as FIBCs are filled or emptied can result in electrostatic discharges, which might pose an ignition hazard for combustible dust or flammable vapor atmospheres within or outside the bag. The four types of FIBCs — Type A, Type B, Type C, and Type D — are based on their characteristics for control of electrostatic discharges. [**652,** 2019]

A.3.3.29.2 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* 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. [**652,** 2019]

A.3.3.30 Lower Flammable Limit (LFL). LFL is also known as minimum explosible concentration (MEC).

A.3.3.31 Minimum Explosible Concentration (MEC). Minimum explosible concentration is defined by the test procedure in ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts.* MEC is equivalent to the lower flammable limit for flammable gases. Because it has been customary to limit the use of the lower flammable limit to flammable vapors and gases, an alternative term is necessary for combustible dusts. [**652,** 2019]

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. [**652,** 2019]

A.3.3.32 Minimum Ignition Energy (MIE). The standard test procedure for MIE of combustible particulate solids is ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air,* and the standard test procedure for MIE of flammable vapors is ASTM E582, *Standard Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures.* [**652,** 2019]

To characterize electrostatic discharge ignition hazards, it is recommended that the ASTM E2019 test be conducted without added inductance, which is equivalent to a capacitive spark discharge.

A.3.3.34 Noncombustible Material. Materials that are reported as having passed ASTM E136, *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.

N **A.3.3.35 Nonconductive.** Typically, a nonconductive material is one having a surface resistivity greater than 10^9 ohms per square or a volume resistivity greater than 10^9 ohm-m. [**652,** 2019]

A.3.3.37 Pneumatic Conveying System. Pneumatic conveying systems include a wide range of equipment systems utilizing air or other gases to transport solid particles from one point to another. A typical system comprises the following:

(1) A device used to meter the material into the conveying air stream
(2) Piping, tubing, hose, etc., used to provide the closed pathway from the metering device to the AMS
(3) An AMS designed for the separation of comparatively large amounts of material from the conveying air/gas stream
(4) An additional metering device (typically a rotary airlock valve or similar device) that might be used to allow discharge of the separated material from the conveying air stream without affecting the differential pressure of the system
(5) An AMD designed to produce the necessary pressure differential and air/gas flow in the system (positive or negative)

A pneumatic conveying system requires the amount of material conveyed by the system to be considered as a major factor in the system pressure drop calculations.

Both positive and negative (i.e., vacuum) differential pressure are used for pneumatic conveying. The decision of which is the best for a specific application should be based upon a risk analysis, equipment layout, and other system operational and cost factors.

Dense phase conveying can also be considered for the application, especially with more hazardous materials (e.g., low MIE). The inherent design and operational features of this approach can provide significant safety and operational advantages over other types of pneumatic conveying systems.

A.3.3.42 Risk Assessment. A risk assessment is a process that performs the following steps:

(1) Identifies hazards
(2) Quantifies the consequences and probabilities of the identified hazards
(3) Identifies hazard control options
(4) Quantifies the effects of the options on the risks of the hazards
(5) Establishes risk tolerance criteria (maximum tolerable levels of risk)
(6) Selects the appropriate control options that meet or exceed the risk acceptability thresholds

[**652,** 2019]

Steps 1 through 3 are typically performed as part of a DHA. Risk assessments can be qualitative, semiquantitative, or quantitative. Qualitative methods are usually used to identify the most hazardous events. Semiquantitative methods are used to determine relative hazards associated with unwanted events and are typified by indexing methods or numerical grading. Quantitative methods are the most extensive and use a probabilistic approach to quantify the risk based on both frequency and consequences. [**652,** 2019]

See SFPE *Engineering Guide to Fire Risk Assessment* or AIChE *Guidelines for Hazard Evaluation Procedures* for more information. [**652,** 2019]

N **A.3.3.48 Ultrafine Particle.** It is important for the user of this standard to be aware that ultrafine particles can present additional hazards that should be considered. Examples of additional hazards are the possible lowering of the MIE or MEC levels, or both, the potential for particulates passing through filtration devices used in dust collection, pneumatic conveying, and so forth. The committee recognizes that the definition for ultrafine particles is wider than the definition in ASTM E2456, *Standard Terminology Relating to Nanotechnology*, but has adopted this increased range because of the additional potential hazards associated with ultrafine particles. When the median size is <0.5 μm (<500 nm), it is more likely that part of the size distribution will be lower than 0.1 μm (100 nm), and therefore a more detailed characterization and hazard assessment specific to ultrafine particles will be necessary.

Nano-powders and nanoparticles, which fall under this definition, are becoming more prevalent as specific-use materials in such industries as additive manufacturing.

A.3.3.52 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.3.3.53 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.3.3.54 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.4.2.1.1 Given the fast acting nature of flash fire, deflagration, and explosions, the stated Life Safety Objective recognizes the difficulty, if not the impossibility, of protecting occupants in the immediate proximity of the ignition. Thus, the stated objective is to protect occupants not in the immediate proximity of ignition. However, all available practices should be employed to ensure the safety of all persons both near and far from the ignition. An example of this might be the standard's prescriptive exception relative to the less than 8 ft^3 (0.2 m^3) air-material separator not requiring protection; however, the intent of the objective is to consider the effect of deflagration to occupants in the immediate area of the small air-material separator and mitigate this hazard if possible. Likewise, the standard has not defined "immediate proximity" in that this could mean within just feet of the hazard or within the same building or structure and leaves that judgment to the user. The intent of the objective is to employ all available and reasonable protection, techniques, and practices to protect all occupants understanding that it might not always be achievable. [**652:**A.4.2.1.1]

A.4.2.3 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.4.2.4.1 Adjacent compartments are those sharing a common enclosure surface (e.g., 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.4.3 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.

N **A.6.1.2** See A.4.3.

N **A.6.1.4** The SFPE *Guidelines for Peer Review in the Fire Protection Design Process* address the process of conducting an independent third party review for a fire protection design.

Δ **A.6.1.5** Chapter 5 of NFPA *101* provides a more complete description of the performance-based design process and requirements. In addition, the SFPE *Engineering Guide to Performance-Based Fire Protection* outlines a process for developing, evaluating, and documenting performance-based designs.

A.6.1.6 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 8.12.

N **A.6.1.7** Chapter 70, "Dust Explosions," of the SFPE *Handbook of Fire Protection Engineering* provides data sources that can be used in a performance-based design. See NFPA 652, Chapter 5 annex material, for qualification of data for use and additional data.

N **A.6.2.2** SFPE S.01, *Engineering Standard on Calculating Fire Exposures to Structures*, provides methodologies to predict thermal boundary conditions for fully developed fires to structures. SFPE S.02, *Engineering Standard on Calculation Methods to Predict the Thermal Performance of Structural and Fire Resistive Assemblies,* provides requirements for the use of methods that predict the thermal response of structures.

A.6.2.5(3) Deflagration vent operation does not constitute rupture of the equipment.

A.6.3 The DHA conducted according to the requirement in Section 7.1 might be useful in identifying the scenarios for Section 6.3.

The fire and explosion scenarios defined in Section 6.3 assume the presence of an ignition source, even those scenarios limited by administrative controls (such as a hot work 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.

Δ **A.6.4.1** The SFPE *Engineering Guide to Performance-Based Fire Protection* outlines a process for evaluating whether trial designs meet the performance criteria. See NFPA 652, Chapter 5 annex material, for qualification of data for use and additional data.

A.7.1.1.1 A DHA is a careful review of the fire and explosion hazards to determine the consequences of what could go wrong and to determine what safeguards could be implemented to prevent or mitigate those consequences. A DHA should be completed as soon as possible. For existing facilities, those processes with the greatest perceived risk should be evaluated first. [**652:**A.7.1.1.1]

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A.7.2.1.3 For many situations, the layer depth method is the easiest and can be used for any application or ceiling height. Either of the mass methods can be used for any ceiling height. Mass method A does not require specific material properties or building strength data. Using mass method A for buildings with greater than 12 m ceiling height does not allow the user increased dust accumulation, compared to mass method B. Mass method B allows the owner/operator the greatest flexibility in addressing dust accumulations and takes into account specific building and material properties. However, this requires more detailed information about the building construction that might not be available for some buildings. When calculating dust loads by either method, include dust on mezzanines. When calculating the allowable volume or mass of dust, the area of the mezzanine is not added to the footprint of the building or room.

A.7.2.1.5 In some cases, such as for fine particulates generated from hardwoods, it is advisable to correct for a settled bulk density in excess of the 20 lb/ft^3 (320 kg/m^3) used in this requirement.

The measurement of bulk density is dependent upon the particle size, shape, and chemical content. Settled bulk density is not the same as tapped bulk density. Settled bulk density is the density as the material has settled in the facility under normal operating conditions. Tapped bulk density is the maximum density that can be achieved without intentional compression. Tapped bulk density measurement numbers are almost always higher than settled bulk density measurement numbers.

Moisture content is a factor that has a profound effect on dust deflagration propagation. Moisture in dust particles raises the minimum ignition temperature (MIT), minimum ignition energy (MIE), and minimum explosible concentration (MEC) by increasing agglomeration of particles.

Moisture content can be determined using the following method:

(1) Weigh the material of which a moisture content is to be determined in the moist, as-received state.
(2) Dry the material for 24 hours in a drying oven set at 167°F (75°C).
(3) Reweigh the sample.

Calculate the moisture content from the following relation:

% MC = [(moist weight) - (dry weight)](100)/moist weight

While no ASTM method currently exists for determining settled bulk density, the following method has been utilized to produce usable results. Because bulk density measurements are used to determine the permissible dust layer depth for hazard assessment, bulk density should be based on the dried weight, not the moist weight; the water in the moist sample does not add combustible material to the mixture.

Recommended Tools: Neoprene or other similar plastic-type gloves, ruler, two natural bristle brushes [4 in. (100 mm) width], scales (that measure grams), pre-weighed container (weighed in grams to the nearest tenth of a gram), and a drying oven.

Recommended Procedure:

(1) Pre-weigh and record container weight.
(2) Locate horizontal surface area where dust is present and evenly distributed across a flat surface. This is an important criterion.
(3) Mark off a 1 ft^2 (0.09 m^2) area. (It is easier if one of the four sides is the horizontal surface ledge.) If an area 1 ft × 1 ft is not available due to the size of the surface use, ½ ft × 2 ft (0.15 m × 0.6 m) or ¼ ft × 4 ft (0.076 m × 1.2 m).
(4) Using the ruler as a guide, carefully scrape the other dust surrounding the marked 1 ft^2 (0.09 m^2) (or other established one square foot dimension) away from the dust square (or rectangle) at least 8–12 in. (0.2–0.3 m). Use the first brush if needed to clean dust away from the 1 ft^2 (0.09 m^2) selected for density measurement [ensuring that the 1 ft^2 (0.09 m^2) area does not receive any of the dust being brushed away].
(5) Measure and record the height [to the nearest 1⁄32 in. (0.8 mm)] of the dust layer as it sits on the horizontal layer. Take a minimum of three to five measurements along the edge of the dust layer to establish an average height [to the nearest 1⁄32 in. (0.8 mm)] of the dust layer.
(6) Take the second clean, natural bristle brush and carefully brush the dust contained inside the 1 ft^2 (0.09 m^2) area into the pre-weighed container.
(7) Dry dust sample as outlined above.
(8) Weigh the dried dust sample and the container together and record the weight in grams.
(9) Subtract the weight of the container from the weight of the dried dust-filled container to obtain the weight of the dried dust in grams. Record the dust weight.
(10) Calculate the volume of the dust layer using the average height measured (in inches) × length (12 in.) × height (12 in.) to obtain cubic inches of volume.
(11) Convert cubic inches to cubic feet.
(12) Convert grams of dust measured to pounds. (Note: 453.6 g = 1 lb).
(13) Divide pounds of dust by cubic feet to establish estimated density in pounds per cubic feet (lb/ft^3).

Example:

Container pre-weight is 500 g.

Average dust height measured is 2 1⁄32 in.

Container plus dust weight is 660 g.

Determination of Dust Volume (ft^3)

(1) 2 1⁄32 in. = 65⁄32 in., or 2.03125 in.
(2) Volume (in.^{3}) = L × W × H = 12 in. × 12 in. × 2.03125 in. = 292.5 in.^{3}
(3) Convert cubic inches to cubic feet. There are 1728 in.^{3} in 1 ft^3.
(4) Volume (ft^3) = Volume (in.^{3}) ÷ 1728 = 292.5 ÷ 1728 = 0.169 ft^3 (0.0048 m^3)
(5) (305 mm × 305 mm × 51.6 mm) = (0.305 m × 0.305 m × 0.0516 m = 0.0048 m^3)

Determination of Dust Weight (lb)

To obtain the weight of the dust, subtract the container weight in grams from the weight of the container containing the dried sample:

(1) 660 g - 500 g = 160 g
(2) Convert grams to pounds. There are 453.6 g in 1 lb, therefore: 160 g ÷ 453.6 g/lb = 0.353 lb (of dust)

Determination of Dust Density

(1) Divide pounds of dust by volume of dust in cubic feet: 0.353 lb ÷ 0.169 ft^3 = 2.087 lb/ft^3
(2) Round off to nearest tenth of a pound = 2.1 lb/ft^3: [0.16 kg ÷ 0.0048 m^3] (33.43 kg/m^3)

A.7.2.3 See Annex D for example calculations applying the layer depth criterion method.

A.7.2.3.2 See Section D.2 for example of how to apply this method.

A.7.2.4 Mass per unit area derived from these mass determination methods can be used to derive a measurable layer depth using the fact that mass divided by settled bulk density equals layer depth. See Section D.3 for an example of how to apply this method.

Because fugitive dust could accumulate in a localized area of the building or room (localized area less than 10 percent of the total floor area), the floor area limit (A_{floor}) used in the equations in 7.2.4.1 or 7.2.4.2 has been set to 2000 m^2. For an example of the calculation of threshold dust mass, see Annex D.

A.7.2.5 See Section D.3 for an example of how to apply this method.

A.7.2.5.1 The dust explosion hazard area equation in 7.2.5.1 originates from the partial volume equation in NFPA 68 which adjusts the amount of venting needed when the design scenario presumes the combustible mixture fills only a part of the enclosure. NFPA 68 uses the ratio of P_{red} to P_{max} and the fill fraction to make this adjustment. P_{red} is the maximum pressure predicted to be developed during a vented deflagration and should be less than the strength of the weakest building structural element not intended to vent or fail. Windows, for instance, might be intended to fail. NFPA 68 sets an upper bound for P_{red}, ensuring that the calculated pressure during the event does not exceed the strength of the enclosure. This upper bound is P_{es}/DLF, the dynamic strength of the weakest building structural element not intended to vent or fail. In the implementation here, the goal is to see if any explosion venting is needed to prevent damage to the main building structural components; thus, P_{red} is equated to its maximum allowable value, based on the building/room design.

In a deflagration, the pressure that is developed changes with the dust concentration. The equation in 7.2.5.1 uses the so-called worst case concentration of dust in a combustible mixture, C_w, as defined in NFPA 68. A conservative way to evaluate the pressure attained at lower average dust concentration is to assume that all of the dust available is concentrated in a smaller volume than the worst case concentration. This smaller volume is a fraction of the total volume, the fill fraction. In the equation in 7.2.5.1, the threshold dust mass, M_{exp}, divided by the product of worst case concentration and building volume is the fill fraction. When the accumulated dust mass is larger than the threshold for the explosion hazard, then the fill fraction is greater than the ratio of P_{es}/DLF to P_{max}, and an explosion hazard exists.

A.7.2.5.1.2 See FPRF, *Report Towards Estimating Entrainment Fraction for Dust Layers*. See NFPA 68 for additional information.

A.7.2.5.2 The dust flash-fire hazard area equation in 7.2.5.2 estimates the fraction of the volume that could be filled by an expanded fireball from burning dust. The room or building volume up to person height is taken as the total volume for this hazard, regardless of actual building height. The threshold for the flash-fire hazard is based on allowing the accumulated dust mass to reach the worst case concentration in an unburnt volume, which, when expanded in a fireball, is only a fraction of the volume described by the product of person height and floor area. The relation in 7.2.5.2 uses as its risk tolerance criterion the probability (p) of an occupant being in the same location as the deflagration flame. This choice implies that some residual risk remains.

Δ **A.7.2.5.2.1** See FPRF *Report Towards Estimating Entrainment Fraction for Dust Layers*. See NFPA 68 for additional information.

A.7.2.6 The risk assessment method in 7.2.6 supplements the DHA required in Chapter 4. It is intended to focus on material properties and inherent design features of the equipment and the facility necessary to determine the extent of the hazard areas.

A.8.4.1.1 Housekeeping for fugitive dusts is most important where the operational intent is that the dust accumulations are not normally present in the occupancy and the building has no deflagration protection features, such as damage limiting/explosion venting construction or classified electrical equipment, and additional personal protection from dust deflagration hazards is not provided. Factors that should be considered in establishing the housekeeping frequency include the following:

(1) Variability of fugitive dust emissions
(2) Impact of process changes and non-routine activities
(3) Variability of accumulations on different surfaces within the room (walls, floors, overheads)

A.8.4.1.3 Unscheduled housekeeping should be performed in accordance with Table A.8.4.1.3(a) to limit the time that a local spill or short-term accumulation of dust is allowed to remain before the local area is cleaned to less than the threshold dust mass/accumulation.

Table A.8.4.1.3(a) shows approximate equivalent depths for the accumulation values in Table A.8.4.1.3(b) when the threshold dust mass/accumulation is 0.2 lb/ft^2 (1 kg/m^2). The owner/operator can use an approximate depth to facilitate communication of housekeeping needs.

A.8.4.1.4 Where the facility is intended to be operated with more than the dust accumulation defined by the owner/operator's chosen criterion in Section 7.2, additional protective measures are necessary. This is a concept similar to the maximum allowable quantities established in the building codes.

A.8.4.2.4 All of the listed precautions might not be required for limited use of compressed air for cleaning minor accumulations of dust from machines or other surfaces between shifts. A risk assessment should be conducted to determine which precautions are required for the specific conditions under which compressed air is being used.

Table A.8.4.1.3(a) Unscheduled Housekeeping

Accumulation on the Worst Single Square Meter of Surface	Longest Time to Complete Unscheduled Local Cleaning of Floor-Accessible Surfaces	Longest Time to Complete Unscheduled Local Cleaning of Remote Surfaces
>1 to 2 times threshold dust mass/accumulation	8 hours	24 hours
>2 to 4 times threshold dust mass/accumulation	4 hours	12 hours
>4 times threshold dust mass/accumulation	1 hour	3 hours

Δ **Table A.8.4.1.3(b) Unscheduled Housekeeping Accumulations**

Accumulation on the Worst Single Square Meter of Surface	Average Depth at 75 lb/ft^3 (1200 kg/m^3)	Average Depth at 30 lb/ft^3 (481 kg/m^3)
>0.2–0.4 lb/ft^2 (>1 to 2 kg/m^2)	>1⁄32–1⁄16 in. (0.8–1.7 mm)	>5⁄64–5⁄32 in. (2.1–4.2 mm)
>0.4–0.8 lb ft^2 (>2 to 4 kg/m^2)	>1⁄16–1⁄8 in. (1.7–3.3 mm)	>5⁄32–5⁄16 in. (4.2–8.3 mm)
>0.8 lb/ft^2 (>4 kg/m^2)	>1⁄8 in. (>3.3 mm)	>5⁄16 in. (>8.3 mm)

A.8.4.2.5 Items that should be included in the housekeeping procedure include the following:

(1) A risk analysis that considers the specific characteristics of the dust being cleaned (particle size, moisture content, MEC, MIE) and other safety risks introduced by the cleaning methods used
(2) Personal safety procedures, including fall protection when working at heights
(3) PPE, including flame-resistant garments in accordance with the hazard analysis required by NFPA 2113
(4) Cleaning sequence
(5) Cleaning methods to be used
(6) Equipment, including lifts, vacuum systems, attachments, and so forth

N **A.8.4.3** Portable vacuum cleaners are self-contained units that typically utilize either an electrically or compressed air powered (with venturi) vacuum source (AMD) and an air-material separator (AMS) that is either wet (i.e., liquid) or dry (i.e., filter media). A single hose connection is normally provided, but larger semiportable units (either on trucks or moved by forklifts) can allow use of more than one simultaneous operator. Typically, when dry filter media is used there is no automatic filter cleaning method; however, with the larger semiportable units automatic filter cleaning is usually provided due to the higher air flows and material/dust loading. [**652:**A.8.4.2.2.1]

N **A.8.4.3.2** Using a portable vacuum cleaner with metal dusts and particles can have risks that are not adequately covered in NFPA 652. However, NFPA 484 has specific sections for use of wet and dry portable vacuum cleaning equipment and on their use with the more exotic metals and alloys such as titanium, aluminum, and so forth. [**652:**A.8.4.2.2.1.2]

N **A.8.4.3.3** Use of portable vacuum cleaning equipment for housekeeping of combustible dusts is subject to the same dust hazards analysis (DHA) as would be a centralized vacuum cleaning system. The combustible dust characteristics, hazards, and risks should be analyzed to determine the best type of portable unit to use and the restrictions on their use. This should also consider the classification of the area of use, personnel protective equipment, and so forth. [**652:**A.8.4.2.2.1.3]

N **A.8.4.3.6** Verification of the path to ground can be visual. [**652:**A.8.4.2.2.1.6]

A.8.4.3.7 The intention of this requirement is to provide specifications for vacuum cleaners that could be used to remove incidental amounts of combustible dusts from unclassified areas in order to maintain the unclassified area designation.

If a large quantity of material is spilled in an unclassified area, the bulk material should be collected by sweeping, by shoveling, or with a portable vacuum cleaner listed as suitable for Class II locations. Vacuum cleaners meeting the requirements in 8.4.3.2 can be used to clean up residual material after the bulk of the spill has been collected.

These requirements for portable vacuum cleaners also should be applied to the use of vacuum trucks for combustible dust. However, there can be other safety issues concerning vacuum truck applications that are not covered within this section. Given that this application might represent a change from normal procedures, operators should also consider the guidance found in conducting a management of change evaluation.

A.8.4.3.7(6) Liquids or wet material can weaken paper filter elements, causing them to fail, which can allow combustible dust to reach the fan and motor.

A.8.4.3.8 The Committee is not aware of vendors providing equipment listed for Class III electrically classified (hazardous) locations. A common practice is to use equipment listed for Class II in areas classified as Class III.

A.8.7.1.2(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 Center for Chemical Process Safety, *Guidelines for Safe Automation of Chemical Processes*.

A.8.7.2.2.4 Periodic cleaning of components is especially important if the blower or fan is exposed to heated air.

A.8.7.2.2.5 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.8.7.2.5.3 For information on maintenance of deflagration venting, see NFPA 68.

A.8.7.3.1 Impairments can include isolating of fire pump controllers, closing of sprinkler system control valves, and isolating and disabling or disconnecting of detection, notification, and suppression systems.

A.8.7.3.2 The impairment procedure consists of identifying the impaired system and alerting plant personnel that the protection system is out of service.

A.8.7.3.3 The facility manager is responsible for ensuring that the condition causing the impairment is promptly corrected.

A.8.7.3.4 When the impairment notification procedure is used, it provides for follow-up by the relevant AHJs. This follow-up helps to ensure that impaired fire and explosion protection systems are not forgotten. When the system is closed and reopened, most companies notify their insurance company, their broker, or the AHJ by telephone or other predetermined method.

A.8.8.1.2 Where a dust explosion hazard or dust flash-fire hazard exists, flame-resistant garments provide a measure of protection for exposed personnel.

A.8.8.2.2(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.8.9.1.1 Qualified contractors should have proper credentials, which include applicable American Society of Mechanical Engineers (ASME) stamps and professional licenses.

A.8.9.2.4 It is suggested that annual meetings be conducted with regular contractors to review the facility's safe work practices and policies. Some points to cover include to whom the contractors would report at the facility, who at the facility can authorize hot work or fire protection impairments, and smoking and nonsmoking areas.

Δ **A.8.11.1** Events where there are injuries, equipment damage, or significant business interruption are subject to investigation. [**652:**A.8.11.1]

In addition to investigation of fires and explosions, it is also a good practice to investigate near misses (events that could have resulted in fires or explosions under different circumstances) and all activations of active fire and explosion mitigation systems. It is important to educate facility personnel on the concept of what a near miss is and to clearly communicate their responsibility for reporting both incidents and near misses. [**652:**A.8.11.1]

The retroactivity of this chapter is not intended to require investigation of incidents that occurred prior to the adoption of this standard.

A.8.11.3 Incident reports should include the following information:

(1) Date of the incident
(2) Location of the incident and equipment/process involved
(3) Description of the incident, contributing factors, and the suspected cause
(4) Operation of automatic/manual fire protection systems and emergency response
(5) Recommendations and corrective actions taken or to be taken to prevent a reoccurrence

The incident report should be reviewed with appropriate management personnel and retained on file for future reference. The recommendations should be addressed and resolved. Incident reports are useful in support of the periodic DHA required by 7.1.4. The owner/operator should consider retaining the incident investigation reports for at least 5 years to be consistent with the DHA review schedule.

A.8.11.4 The owner/operator should consider sharing relevant learnings with other facilities within the company.

A.8.12 It is essential to have thorough written documentation, as the slightest changes to procedures, processes, resources, staffing, and equipment, including equipment from suppliers, can have a dramatic impact on the overall hazard analysis. Change includes something as benign as process materials sourcing from a different manufacturer, the same raw material manufacturer using new methods to produce the product, or changes in formulation. These changes from a supplier's end can impact the characteristics of the processes and materials. Individuals involved should include those involved in the process such as maintenance, engineering, and purchasing personnel, and all others as deemed necessary. Staffing and job tasks are not intended for shift changes, but for overall staff and their representative tasks. For reference, see the documentation form in ANSI/AIHA Z10, *Occupational Health and Safety Management Systems*. [**652:**A.8.12.1]

The following changes in material or process should warrant a management of change review per Section 8.12, and new samples should be collected and analyzed:

(1) New process equipment is installed that presents new hazards.
(2) New operating conditions for existing equipment create a new hazard.
(3) A new material is used in the process.

[**652:**A.8.12.1]

A.8.12.1(1) The proposed change and why it is needed should be described. It should include sufficient technical information to facilitate review by the approvers, address adverse effects that could occur, and describe how such effects would be mitigated by the proposed change. [**652:**A.8.12.2(1)]

A.8.12.1(2) Some fire and explosion protection systems introduce additional hazards into the process environment. These hazards can include, but are not limited to, energy in suppression canisters, asphyxiation hazards from inert gases, and mechanical laceration/amputation hazards from explosion isolation systems. While these are not fire or explosion hazards, they should be addressed as part of the management of change review per this document so that appropriate controls can be applied. [**652:**A.8.12.2(2)]

A.9.1.2 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.9.2.1.2.1 ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, is a typical test method used. Equivalent test methods can also be used.

A.9.2.1.3.1 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.9.2.1.3.2 The assertion of separation must recognize the dust accumulation on all surfaces in the intervening distance, including floors, beam flanges, piping, ductwork, equipment, suspended ceilings, light fixtures, and walls. Process equipment or ductwork containing dust can also provide a connecting conduit for propagation between accumulation areas. The National Grain and Feed Association study "Dust Explosion Propagation in Simulated Grain Conveyor Galleries" has shown that a layer as thin as $\frac{1}{100}$ in. (0.25 mm) is sufficient to propagate flame in a limited expansion connection, such as an exhaust duct or a hallway. In the subject study the flame propagated for at least 80 ft (24.4 m).

A.9.2.2.3 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.9.2.2.7.1 This provision requires shorter travel distances and wider egress pathways, resulting in shorter egress times for those occupancies with high hazard contents. In many cases, it also requires multiple means of egress so that occupants do not have to travel past a hazardous situation while evacuating the facility.

A.9.2.2.9.1 An appropriate test method is ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials.*

Δ **A.9.2.2.9.2** An appropriate test method is in accordance with NFPA 252.

A.9.2.2.10 The use of loadbearing walls should be avoided to prevent structural collapse should an explosion occur.

A.9.2.3 The design of deflagration venting should be based on information contained in NFPA 68.

Δ **A.9.2.3.1** 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.

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

Δ **A.9.2.3.2** For further information on restraining vent closures and fireball impingement areas, see NFPA 68.

Δ **A.9.3.1** 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 9.4.3.)*
(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.9.3.1.3 A means to determine protection requirements should be based on a risk assessment, 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.9.3.1.4 These devices reduce the frequency or likelihood that the sparks will cause a deflagration but do not eliminate the need for deflagration isolation devices. The abort gate cannot be relied on to serve as a deflagration isolation device because the response time is relatively slow and construction is usually unsuitable for withstanding explosion pressures.

Additional information on spark extinguishing systems can be found in Annex C.

A.9.3.2.1.2 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.

A.9.3.2.2 Historically, 9.3.2.2 required that the fixed bulk storage vessel be constructed of noncombustible materials, which usually meant a metallic material. However, there are some particulates that represent a serious corrosion threat or where contamination from the materials of construction introduces product quality issues, therefore nonmetallic construction is required. The materials of construction for a bulk storage vessel should not increase the fire protection challenge.

A.9.3.2.3.2.2(2) 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.9.3.2.3.3.2 See A.9.3.2.3.2.2(2).

A.9.3.2.4 Horizontal projections can have the tops sharply sloped to minimize the deposit of dust thereon. Efforts should be made to minimize the amount of surfaces where dust can accumulate.

A.9.3.2.5 For information on designing deflagration venting, see NFPA 68.

A.9.3.3.1.1 For additional information, see ASTM E2012, *Standard Guide for the Preparation of a Binary Chemical Compatibility Chart*.

Δ **A.9.3.3.1.5** The design of the pneumatic conveying, dust collection, and centralized vacuum cleaning 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 listed in A.9.3.3.1.5(1) through A.9.3.3.1.5(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

Δ **A.9.3.3.2** The design of a pneumatic conveying, dust collection, or centralized vacuum cleaning 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 such as location, construction, ventilation ductwork, volume of outside air at standard temperature and pressure that is introduced for safety ventilation, and control wiring diagrams.

Dust collection systems and centralized vacuum cleaning systems handling combustible dusts usually use branched duct networks with multiple pickup points and variable material loading. In contrast, dilute phase and dense phase pneumatic conveying systems typically are linear systems with controlled infeed and consistent material loading. Pneumatic conveying systems generally represent a lower deflagration risk. However, that does not mean there is no deflagration risk. Risk analysis should be used to determine the level of risk involved and the correct means to minimize that risk.

A.9.3.3.2.2 These systems are designed for specific safety and performance requirements. Modifications to the system can significantly change the ability of the system to provide the original design performance. An analysis of any proposed changes should be done in accordance with Section 8.12 (concerning management of change) to ensure the system will still be able to meet safety and performance requirements.

A.9.3.3.2.4 The minimum gas velocity to transport materials varies considerably due to the material characteristics, conveying rates, conveying distances, and other factors. If the velocity falls below the minimum requirement, plugging and other upset conditions could occur and lead to an unsafe operating condition. Typically the minimum gas velocities are established by testing or are based on existing data from the system designer or vendor.

A.9.3.3.2.5 Rotary valves and diverter valves are not addressed in the ASME *Boiler and Pressure Vessel Code* or ASME B.31.3, *Process Piping*, so they would not be required to comply with those codes.

A.9.3.3.2.5.1 Except for inerted systems, it is preferable to design systems that handle combustible particulate solids to operate under negative pressure.

A.9.3.3.2.6.1 Proper dust collection design requires that a minimum air volume flow be maintained for each dust collection source point (such as a hood). This value should be determined as part of the design process. This is the value that should be documented to allow for field testing to determine if the system is providing that flow and operating properly.

A.9.3.3.2.6.2 ACGIH *Industrial Ventilation: A Manual of Recommended Practice for Design* has extensive information on the design basis for dust collection hoods and the necessary minimum air volumes and velocities to ensure the containment, capture (i.e., collection), and control of the aerated dusts being generated.

A.9.3.3.2.6.3 Proper system design requires that air flows in the various branch lines be balanced to ensure minimum air volume flow at each dust source collection point. When a branch line is disconnected, blanked off, or otherwise modified, it changes the air flows in all the other branches of the system. This can lead to an imbalance of air flows, resulting in flows below the minimum required to keep dust from accumulating in the ducts.

A.9.3.3.2.6.4 Adding additional branch lines for additional dust sources to an existing dust collection system will result in lower air volumes and duct velocities for the existing portions of the system. Without provisions for additional system performance, this can result in a system performing below the minimum required for keeping the ducts free from material accumulations. It is also possible that modifications could result in failure of the main equipment items.

A.9.3.3.2.6.5 According to ACGIH *Industrial Ventilation: A Manual of Recommended Practice for Design*, the duct air velocity can range from a minimum of 3500 fpm (18 m/s) to significantly higher levels. However, that document is for all dusts, including noncombustible dusts. A velocity of 4000 fpm (20 m/s) is recommended as a minimum value for the conveying of combustible dusts. Also, some combustible dusts have material characteristics (e.g., cohesiveness, adhesiveness, particle shape and size, particle density) that require significantly higher duct velocities to minimize the possibility of accumulations in the ducts. For instance, NFPA 484 requires a minimum duct velocity of 4500 fpm (23 m/s) for metal dusts.

A.9.3.3.2.6.6 Dust collection systems and centralized vacuum cleaning systems handling combustible dusts usually use branched duct networks with multiple pickup points and variable material loading. In contrast, dilute phase and dense phase pneumatic conveying systems are typically linear systems with controlled infeed and consistent material loading. Dust collection systems for combustible dusts represent a significant increase in deflagration risk compared with most pneumatic conveying systems. A properly designed system is critical to minimizing that risk. For guidance on determining proper dust collection system design, refer to ACGIH *Industrial Ventilation: A Manual of Recommended Practice for Design.*

A.9.3.3.2.6.8 Where combustible dust emissions are likely, they should be managed with a dust collection system. The operator should not rely on the HVAC system to prevent dust accumulations. It is recognized that dust collection systems might not capture 100 percent of the dusts released from localized sources. It is not the intent of this requirement to prohibit the use of HVAC systems where incidental amounts of airborne dust are present and the HVAC system has been designed to address this hazard. Special attention should be given to areas where low air velocity exists and dust can settle out, such as the return air plenum.

A.9.3.3.2.7 Centralized vacuum cleaning systems represent a significant deflagration risk due to the fact that the system is designed to both collect and convey combustible dusts and that tramp metals and other foreign materials that could create an ignition source can enter the system through the vacuuming process. However, through proper design and protection of the system against deflagration, this system can provide for the removal of combustible dusts from plant areas where dust accumulations represent a risk to personnel and property. Furthermore, the dust, once removed through the vacuuming process, can be located in an area where it can be properly handled with minimal risk.

A.9.3.3.2.7.1 No more than two simultaneous hose connection stations should be allowed on any one line to the AMS. This is to ensure that adequate transport velocity can be maintained with just a single operator on the same line. Multiple lines to the AMS can be used to allow for more than two simultaneous operators on the whole system (with no more than two simultaneous operators allowed on each line).

The minimum conveying velocity will vary with the typical combustible dusts being conveyed. Usually, the minimum conveying velocities will be the same as the minimum required for pneumatic conveying of the same material.

A.9.3.3.2.7.2 Hose diameters of 1.5 in. (38 mm) and/or 2.0 in. (50 mm) i.d. are usually used for housekeeping purposes. Hoses should be 25 ft (7.6 m) or less in length. In most systems, the pressure losses (i.e., energy losses) through the hose represent as much as 50 percent of the overall system differential pressure requirements. If the hose diameter is too large, the flow can be insufficient to maintain transport velocity through the hose. Conversely, if the hose diameter is too small, the flow restriction of the hose can produce a low velocity in the branch line. Shorter hose lengths can be used to improve system performance, but they should be long enough to accomplish the intended tasks while avoiding the need for field modifications such as splicing or coupling hoses.

A.9.3.3.2.7.3 The accumulation of static electrical charge on conductive or static-dissipative vacuum cleaning tools, hoses, and couplings can be prevented through grounding of these system components. However, there is a potential for the accumulation of static electrical charge on particulate solids that are transported through these components. Often this can pose an electrostatic ignition concern in the AMS, which would then warrant the application of appropriate control measures. Creation of static electrical charges is of greater concern when low MIE combustible dusts are being vacuumed.

A.9.3.3.2.7.4 The AMS should not be used as a combustible dust storage device due to the potential of bridging and plugging of the discharge. A rotary airlock valve can be used to provide for continuous discharge of the separated dusts; alternatively, a slide valve can be used where dust loadings are light, provided that the material is removed frequently enough to prevent bridging and plugging. The container below the rotary valve or other continuous discharge device should be designed for the type of material collected and the typical rates of material collected and to minimize the creation of aerated dusts during the discharge of the material from the AMS into the container. It is also important to maintain regular emptying or replacement of the collected material container to minimize the risk of overfilling.

A.9.3.3.3 The requirements in 9.3.3.3 are applicable to dilute phase pneumatic conveying systems. Dense phase systems require a separate analysis.

A.9.3.3.3.2 Some chemical and plastic dusts release residual flammable vapors such as residual solvents, monomers, or resin additives. These vapors can be released from the material during handling or storage. Design of the system should be based on a minimum airflow sufficient to keep the concentration of the particular flammable vapor in the airstream below 25 percent of the LFL of the vapor.

A.9.3.4.3 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.9.3.6.3 Where flexible hoses are used, they should be of the minimum length to accommodate the intended function. Most flexible hoses produce large pressure drops per unit of length, reducing efficiency.

A.9.3.6.4 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 (often called a *reducer*) 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 that both situations be avoided.

A.9.3.6.5 Isolation devices in accordance with 9.7.2 are provided to prevent deflagration propagation between connected equipment. According to 9.7.2, 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.9.3.8.2 For information on deflagration pressure relief, see A.9.7.1.1(2).

A.9.3.8.2.4 High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust.

A.9.3.10 It is recommended that bucket elevators be located outside of buildings wherever practicable. Although explosion protection for bucket elevators is required in 9.3.10.1, an additional degree of protection to building occupants and contents is provided by locating the bucket elevator outside of the building.

A.9.3.10.4.1 Methods by which this cutoff can be achieved include sensing overcurrent to the drive motor or high motor temperature.

A.9.3.10.5.2 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 for more information.

A.9.3.10.7 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.

A.9.3.10.8.1 The motor selected should not be larger than the smallest standard motor capable of meeting this requirement.

A.9.3.11 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 9.7.1.)*

A.9.3.11.2.1 Methods by which this shutoff can be achieved include sensing overcurrent to the drive motor or high motor temperature.

A.9.3.12.2.1 The Committee is aware of installations of AMDs (electrical motor and impeller) inside the clean-air plenum of AMSs. Standard duty AMDs are not suitable for such service. Because of the potential for failure of the filter medium or other malfunction, the clean-air side of air-material separators should be considered as at least a Class II, Division 2, location with regard to proper installation of electrical equipment. NFPA 91 also addresses AMD materials of construction and clearances, including specific requirements where combustible materials could be present.

A.9.3.12.2.2 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 AMS in the pneumatic conveying system.

A threshold concentration limit of 10 percent of the MEC has been 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.

A.9.3.12.2.3 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.9.3.12.2.5 The production of mechanical sparks is only one possible ignition mechanism from a fan or blower. Frictional heat due to contact between moving parts (misalignment) or bearing failure can present an ignition source both in the fan and downstream. Additionally, these failure mechanisms can result in a decrease in airflow through the AMD, which can result in an increase in the combustible dust concentration coincident with the creation of an ignition source.

A.9.3.13.1.1.2 Where deflagration venting is used, its design should be based on information contained in NFPA 68. 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 AMS, 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.9.3.13.1.1.2(4) Enclosureless dust collectors are not meant for use with most dusts created during the venting of process equipment or other aerated dust sources. Fine dust will rapidly blind the filter, which results in reduced performance and a significant increase in deflagration hazards associated with the system operation and performance.

A.9.3.13.1.1.2(4)(d) Many of the enclosureless dust collectors are manifolded into multiple bags with containers. The 5000 cfm limit refers to the overall airflow through the assembly and not just to a single bag with collected material container.

A.9.3.13.1.1.2(4)(e) *NFPA 70*, in 502.125(B), states: In Class II, Division 2, locations, motors, generators, and other rotating electrical equipment shall be totally enclosed non ventilated, totally enclosed pipe-ventilated, totally enclosed water-air-cooled, totally enclosed fan-cooled or dust-ignition proof for which maximum full-load external temperature shall be in accordance with 500.8(D)(2) of *NFPA 70* for normal operation when operating in free air (not dust blanketed) and shall have no external openings.

A.9.3.13.1.1.2(4)(h) Enclosureless dust collectors are often manifolded into multiple bags (with collected material containers). Each such manifolded assembly must be separated by the required 20 ft or 6.1 m.

A.9.3.13.1.1.2(4)(i) MIE is determined by testing the material as received with respect to particle size.

A.9.3.13.1.4 For design requirements for fast-acting dampers and valves, flame front diverters, and flame front extinguishing systems, see NFPA 69.

Δ **A.9.3.13.1.6.3** Recommended design, maintenance, and operating guidelines for recirculation of industrial exhaust systems, as described in Chapter 7 of ACGIH *Industrial Ventilation: A Manual of Recommended Practice for Design* should be followed.

When "clean air" is being returned to the facility interior, it is important to understand that the return air might contain some residual dust depending on the type of AMS. Usually the filter media in a dust collector trap the large particles, but there might be very fine material that manages to get through the filter media and accumulates downstream within the clean air plenum and return air duct. A routine maintenance program is necessary to ensure that the clean air side of the dust collection system remains sufficiently clean to achieve the safety objectives of the standard. The use of HEPA secondary filters can often reduce the frequency of inspection but should not be expected to eliminate it.

A.9.3.13.1.6.3(2) The system should be designed, maintained, and operated according to accepted engineering practice, and the AMS efficiency should be sufficient to prevent dust in the recycled air from causing hazardous accumulations of combustible dust in any area of the building.

A.9.3.13.1.6.3(3) 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 29 CFR 1910.146.

N **A.9.3.13.1.6.4** Presently a standard test method does not exist to provide listing or certification for this type of device for this purpose. The prohibition is being retained until there is listing by a nationally recognized testing laboratory or proof this type of device can be used successfully for this purpose.

Currently there are strong concerns regarding the differential pressure effects, material accumulation effects, and so forth, which could lead to problems that represent additional, uncontrolled or unmitigated hazards.

A.9.3.13.2.3.5 See NFPA 68.

A.9.3.14 Size reduction machinery includes equipment such as mills, grinders, and pulverizers.

A.9.3.15 Particle separation devices include screens, sieves, aspirators, pneumatic separators, sifters, and similar devices.

A.9.3.15.3 For information on designing deflagration venting, see NFPA 68.

A.9.3.15.3.2 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.9.3.17 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.9.3.17.9 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."

N **A.9.3.18.1** Ultrafine particles are produced either as part of a process or as a by-product of other process operations such as milling, grinding, polishing, pneumatic conveying, and so forth. Due to the extremely small particle sizes involved, such combustible dust particles represent hazards and material control problems that might not be fully covered by the various NFPA standards on combustible dusts.

This section is provided to assist the user in understanding the possible additional hazards created by the very small particle sizes involved. Currently there is limited information on the effects of extremely small particle sizes on the combustibility and/or explosivity of the combustible dust when compared to the larger particle sizes. In some cases there might be significant differences, and in others no significant difference can be determined.

Due to the extremely small particle sizes involved, many of the typical systems used for particle control (e.g., dust collectors, filters) will not be effective. When a significant fraction of ultrafine particles is present such hazards should be considered.

N **A.9.3.18.3** Due to the extremely small particle sizes involved, the process and material control equipment used in a system might not provide the needed dust control and/or containment normally expected. A typical example would be an AMS. A typical AMS might not be able to provide efficient control of particles less than 0.5 μm (500 nm), thus allowing such particles to escape filtration. If sufficient amounts of these smaller particles are allowed to accumulate in an area they can represent a significant hazard. Any DHA should consider the unique problems associated with effectively handling such particles.

N **A.9.3.18.5.1** Processes used to produce ultrafine particles typically have specific hazards associated with the actual process. These processes are often unique to the process used to create the ultrafine particle. Such hazards should be considered along with the inherent hazards of the ultrafine particle.

A.9.4.1.2.3 Specific attention should be paid to combustible particulate solids where they are introduced into the process stream. Some sources of particulates 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.9.4.1.2.3(a) and Figure A.9.4.1.2.3(b) for examples of foreign material removal.

Δ **A.9.4.1.3** 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 9.4.1.3 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 9.8.3 should be considered. Certain materials that can self-heat to ignition require means to minimize the hazard. It is permitted to utilize, but not limited to, methods such as mechanically disturbing the material to interrupt the chemical reaction, inerting any equipment containing self-heating materials, reducing moisture content to stop the chemical reaction, or reducing the mass of the material.

A.9.4.1.4 Transmission of power by direct drive should be used, where possible, in preference to belt or chain drives.

A.9.4.1.5 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.

N **A.9.4.1.5.4** The intent of this requirement is to address bearings that can have accumulations of dust on them or be in a suspended dust cloud. The concern is that if the bearing overheats it can present an ignition source to the dust cloud or the dust layer.

Such equipment can include, but is not limited to, the following:

(1) Bucket elevator head and boot areas
(2) Particulate size-reduction equipment
(3) Blenders
(4) Belt-driven fans where combustible dust is present

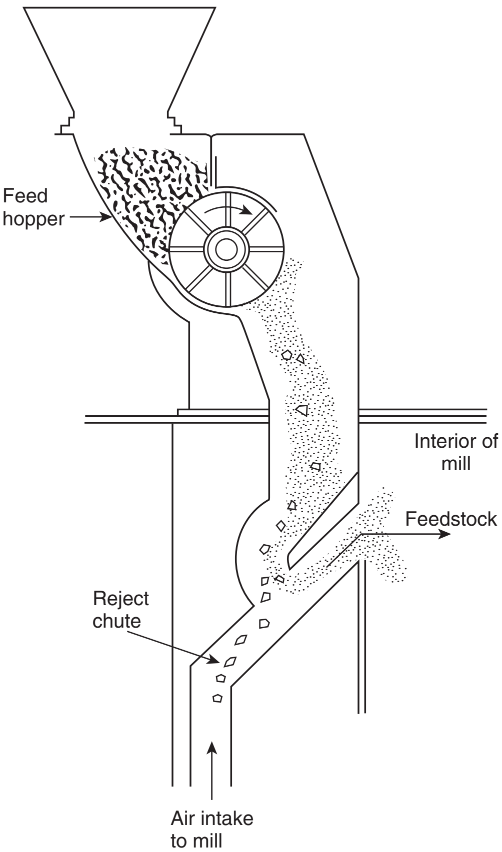


FIGURE A.9.4.1.2.3(a) Pneumatic Separator.

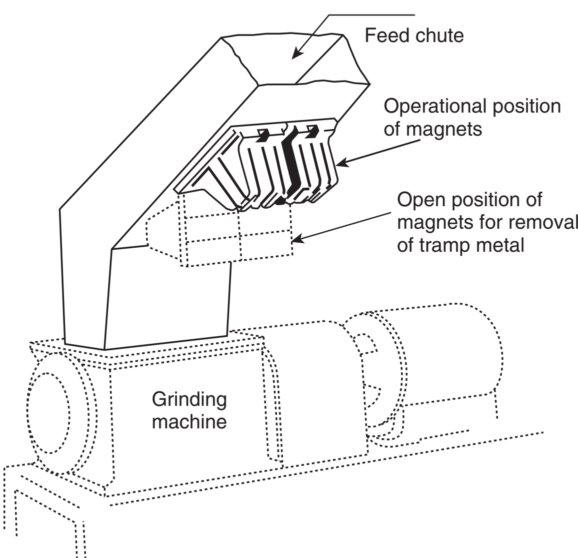


FIGURE A.9.4.1.2.3(b) Magnetic Separator.

In addition to monitoring bearing temperatures directly, precursors to bearing or shaft overheating can also provide early warnings of bearing or shaft deterioration. These precursors include excessive shaft vibration or speed reduction. Monitoring can consist of periodic manual checks, installed devices, or automated monitoring. [**652:**A.9.4.5.2]

N **A.9.4.1.5.6** The risk assessment should include the potential for propagation of an explosion from an unmonitored unit. [**652:**A.9.4.5.4]

A.9.4.2.2 Refer to NFPA 499. See also Table A.9.4.2.2 (Note: Table A.9.4.2.2 does not apply to Class III materials).

Threshold dust accumulation that would require electrically classified equipment is tied to the likelihood of the accumulations and the housekeeping policy as shown in Table A.9.4.2.2 provided as guidance. However, neither the *NFPA 70* nor NFPA 654 provides a mandatory prescription for the user to decide how much dust accumulation should trigger the use of classified equipment.

When evaluating how much dust is too much for electrical equipment, several factors need to be considered. *NFPA 70* provides Class II, Division 1 and Division 2 criteria in article 500. It states that a Division 2 location is one of the following:

(1) A location in which combustible dust due to abnormal operations might be present in the air in quantities sufficient to produce explosive or ignitible mixtures
(2) A location in which combustible dust accumulations are present but are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus but could, as a result of infrequent malfunctioning of handling or processing equipment, become suspended in the air
(3) A location in which combustible dust accumulations on, in, or in the vicinity of the electrical equipment could be sufficient to interfere with the safe dissipation of heat from electrical equipment or could be ignitible by abnormal operation or failure of electrical equipment

The first two criteria deal with the potential for presence of a dust cloud in the location under abnormal conditions. The third criterion deals with the potential for ignition of a dust accumulation by unprotected hot surfaces, either internal or external to the electrical equipment under normal as well as abnormal conditions. The first and second criteria are process related, and the third criterion is directly related to the layer thickness on the electrical equipment.

The likelihood of a dust to be heated to ignition temperature when accumulated on the outside of an electrical enclosure or a piece of electrical equipment is a function of the thickness, thermal conductivity, density, and combustion chemistry of the dust layer as well as the fractional coverage of the equipment's heat dissipation area and the time it remains on the heated equipment.

Both NFPA 654 and NFPA 499 recognize early ignition possibilities due to dehydration and carbonization phenomena but do not offer any methods to evaluate this potential. The appropriate electrical equipment for a given dust is that equipment designed with a maximum surface temperature, designated by the T-code, less than the lower of the layer or cloud ignition temperature of the specific dust. The layer ignition temperature can be determined according to ASTM E2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers,* using at least a ½ in. (13 mm) layer thickness. This is greater than the ⅛ in. (3.2 mm) nominal dust layer establishing a Division 1 hazardous (classified) area per NFPA 499, thus providing a safety factor. NFPA 499 also establishes that a Division 2 hazardous (classified) area would exist when the dust layer prevents clearly discerning the underlying floor color. Given that dust layers tend to be thicker on the upward-facing surfaces of equipment while heat dissipation area is more evenly distributed, it can be seen that this is a significantly conservative approach.

A.9.4.3 See NFPA 77 for information on this subject.

Several types of electrostatic discharges are capable of igniting combustible dusts and hybrid mixtures. The requirements in 9.4.3 are intended to protect against the following four types of discharge: Brush, cone (or bulking brush), propagating brush, and capacitive spark. [**652:**A.9.4.7]

Brush discharges occur when electrostatic charge accumulates on a nonconductive surface and is discharged to nearby conductor. These discharges have a maximum theoretical discharge energy of 3 mJ–5 mJ, which is sufficient to ignite most flammable vapors and gases. There are no records of brush discharges igniting combustible dusts outside of laboratory settings. In the first edition of this standard, a 3 mJ MIE limit was applied as a minimum criterion for the use of nonconductive system components. The intent of this criterion was to ensure that brush discharges were prevented when the MIE was less than the theoretical upper limit of brush discharge energy. However, even where combustible dusts have MIE values less than 3 mJ, the diffuse nature of a brush discharge makes it a less effective ignition source than the capacitive spark used for determining the MIE value. [**652:**A.9.4.7]

Cone or bulking brush discharges occur when resistive solids are transferred into containers where the charge accumulates in the bulk material. The compaction of the charges by gravity creates a strong electric field across the top surface of the material. When the field strength exceeds the breakdown voltage of air, a cone discharge occurs across the surface of the pile terminating at a conductive object (typically the vessel wall.) The energy of a cone discharge is dependent on the size of the container (among other parameters), and discharges up to 20 mJ can occur in process equipment. One particular situation in which cone discharges can occur is in filling FIBCs. For nonconductive containers and vessels such as FIBCs, discharges can occur across the full width (as opposed to the radius or half-width for conductive vessels). For a typical nonconductive FIBC, discharges up to 3 mJ can occur. [**652:**A.9.4.7]

Propagating brush discharges occur when the rapid flow of particulate material generates a high surface charge on a thin nonconductive surface. The presence of this charge on one side of the material induces an opposite charge on the other side, essentially forming a capacitor. If the voltage difference across the material exceeds the material's breakdown voltage, then a pinhole channel is created at a weak spot in the material and the charges on the opposite surfaces are discharged through the channel. Propagating brush discharge energy can

Table A.9.4.2.2 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 ⅛	Infrequent[c]	Clean up during same shift.	Unclassified; however, electrical enclosures should be dusttight[f,g]
1⁄32 to ⅛	Continuous/frequent[d]	Clean as necessary to maintain an average accumulation below 1⁄16 in.	Class II, Division 2
>⅛	Infrequent[c]	Immediately shut down and clean.	Class II, Division 2
>⅛	Continuous/frequent[d]	Clean at frequency appropriate to minimize accumulation.	Class II, Division 1

Notes:
(1) Note: For SI units, 1 in. = 25.4 mm.
(2) This table does not apply to Class III materials.
[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.

be on the order of 1000 mJ. Propagating brush discharges cannot occur if the material is sufficiently thick (greater than 8 mm) or has a sufficiently low breakdown voltage (less than 4 kV for films or sheets or less than 6 kV for woven materials). The presence of an external grounding wire on a nonconductive object will not prevent a propagating brush discharge. [**652:**A.9.4.7]

Capacitive spark discharges occur when the voltage difference between two conductive objects exceeds the breakdown voltage of the medium between them (typically air). Capacitive sparks can ignite both flammable vapors/gases and combustible dusts. [**652:**A.9.4.7]

For more information on electrostatic discharges, refer to NFPA 77 and IEC TS 60079-32-1, *Explosive atmospheres — Part 32-1: Electrostatic hazards, guidance*. [**652:**A.9.4.7]

A.9.4.3.2 Bonding minimizes the potential difference between conductive objects. Grounding minimizes the potential difference between objects and ground.

A.9.4.3.2.1 In this context, the system is intended to mean the fixed equipment and internals and does not include portable containers or packaging being filled or emptied.

N **A.9.4.3.2.2(1)** This requirement is intended to prevent ignition of hybrid mixtures or flammable gas/vapor atmospheres by brush discharges from nonconductive surfaces. [**652:**A.9.4.7.1.2(1)]

N **A.9.4.3.2.2(2)** This requirement is intended to prevent ignition of combustible dusts by the isolation of conductive particulate solids where they can accumulate charge and create capacitive spark discharges to grounded conductive objects. [**652:**9.4.7.1.2(2)]

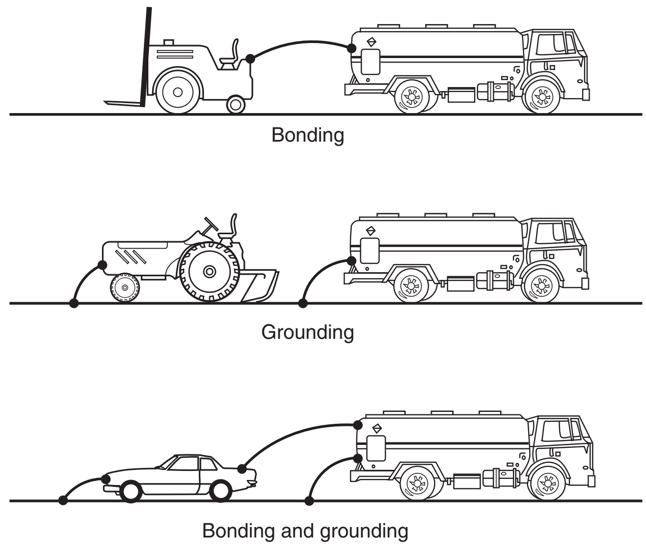
N **A.9.4.3.2.2(3)** This requirement is intended to prevent ignition of combustible dusts by capacitive sparks from isolated process equipment. [**652:**9.4.7.1.2(3)]

A.9.4.3.2.2(4) This requirement is intended to prevent ignition of combustible dusts by propagating brush discharges. Pneumatic conveying is an example of a process operation that can generate high surface charging. [**652:**A.9.4.7.1.2(4)]

Δ **A.9.4.3.2.3** This requirement is intended to prevent ignition of combustible dusts, flammable gas/vapor atmospheres, or hybrid mixtures by capacitive sparks from isolated process equipment. Where the bonding and grounding system is all metal, resistance in continuous ground paths typically is less than 10 ohms. Such systems include those having multiple components. Greater resistance usually indicates that the metal path is not continuous, usually because of loose connections or corrosion. A permanent or fixed grounding system that is acceptable for power circuits or for lightning protection is more than adequate for a static electricity grounding system. [**652:**A.9.4.7.1.3]

See Figure A.9.4.3.2.3 for illustrations of bonding and grounding principles. [**652:**A.9.4.7.1.3]

N **A.9.4.3.3** Electrostatic charge generation on power transmission belts occurs due to contact and separation between the belt and pulleys and is dependent on the width of the belt, speed of rotation, and belt tension. IEC 60079-32-1, *Explosive Atmospheres — Part 32-1: Electrostatic Hazards, Guidance*, provides detailed requirements based on belt speed and hazard area classification. It does not require static-dissipative belts in Zone 2 (Class I Division 2) or Zone 22 (Class II Division 2) areas, unless experience shows that incendive discharges occur frequently. The resistance is measured at the inner side of the mounted transmission belt, between an electrode halfway between the two pulleys and ground.



N **FIGURE A.9.4.3.2.3 Bonding and Grounding. [652:Figure A.9.4.7.1.3]**

A.9.4.3.4 Where a hose has a conductive, spiral reinforcing wire, the wire should be bonded to any conductive component(s) at the end(s).

N **A.9.4.3.5** In order to properly specify a flexible connector for combustible dust service, it is necessary to know the end-to-end resistance. The end-to-end resistance is typically not specified by the suppliers of flexible connectors. This makes it necessary for the user to measure it. ISO 8031, *Rubber and plastics hoses and hose assemblies — Determination of electrical resistance and conductivity*, provides methods to determine the end-to-end resistance. For convenience, the following is a brief description of a similar procedure:

(1) It is preferred to measure the actual flexible connector to be used, but if it is too long for this to be practical, a shorter length (for example, 6 in. to 24 in.) can be used. The measured end-to-end resistance per unit length can then be multiplied by the total flexible connector length to get the overall flexible connector end-to-end resistance.
(2) The flexible connector should be placed on a nonconductive surface, such as a rigid sheet of PTFE, polyethylene, or polypropylene. It is important that neither the flexible connector or megohm meter metal connections are touched by the operator's bare skin during the measurement as this will short the circuit. In addition, the rigid polymer sheet and flexible connector should be dry during the measurement.
(3) The leads on a megohm meter should be contacted on the inside surface of the flexible connector at each end. This should be done at several points on the inside surface to ensure that a consistent reading is obtained. Care should be taken to make measurements at the greatest distance from any supporting wires in the flexible

connector to avoid measuring the resistance across the wire. The readings should be taken at approximately 500 V.

[**652:**A.9.4.7.1.4]

N **A.9.4.3.5.1** Flexible connectors wear out over time. The intent of this statement is that existing connectors would be replaced with compliant flexible connectors at the end of their service life. [**652:**A.9.4.7.1.4.1]

N **A.9.4.3.5.3** Propagating brush discharges, which are generally considered to be the most energetic type of electrostatic discharge, are usually taken to be on the order of 1000 mJ. 2000 mJ provides a margin of safety.

A.9.4.3.6 A more detailed description of FIBC ignition hazards can be found in IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC).* [**652:**A.9.4.7.4]

Δ **A.9.4.3.6.1** Induction charging of ungrounded conductive objects, including personnel, should be addressed as part of the dust hazards analysis. The DHA should also consider that higher rates of transfer into and out of the FIBC increase the rate of charge generation. Consideration should also be given to the possibility of surface (cone) discharges while the FIBC is being filled, regardless of FIBC type. [**652:**A.9.4.7.4.1]

For additional information on these phenomena, refer to NFPA 77. The use of internal liners in FIBCs can introduce additional electrostatic ignition hazards and should be subject to expert review prior to use. [**652:**A.9.4.7.4.1]

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N **A.9.4.3.6.2** Type A FIBCs are capable of producing propagating brush discharges that are capable of igniting combustible dusts and flammable vapors/gases. Type A bags are capable of producing brush discharges that are capable of igniting flammable vapors/gases. Type A FIBCs can allow conductive particulate solids to become isolated conductors, leading to capacitive spark discharges. [**652:**A.9.4.7.4.2]

N **A.9.4.3.6.3** Type B FIBCs are capable of producing cone (bulking brush) discharges across the full width of the FIBC with maximum discharge energies of ~3 mJ. These discharges are capable of igniting flammable vapors/gases and combustible dusts with MIE <3 mJ. Type B bags are capable of producing brush discharges that are capable of igniting flammable vapors/gases. Type B FIBCs can allow conductive particulate solids to become isolated conductors, leading to capacitive spark discharges. [**652:**A.9.4.7.4.3]

N **A.9.4.3.6.4** Type C FIBCs are capable of producing capacitive spark discharges if the grounding tab is not connected. Type C FIBCs are not capable of producing brush or propagating brush discharges, but could be capable of producing cone discharges across the half-width of the bag. Some Type C FIBCs have an internal coating that can isolate conductive particulate solids from ground, producing the potential for capacitive spark discharges from the conductive material to the grounded conductive elements of the bag. Per IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, Type C FIBCs are permitted to be used for Zone Group IIA and IIB gases but not Group IIC. [**652:**A.9.4.7.4.4]

N **A.9.4.3.6.5** Type D FIBCs use low energy corona discharges to dissipate static charges from the bag surface. Corona discharges are capable of igniting flammable gases or vapors with MIE less than 0.14 mJ. Type D FIBCs are not capable of producing brush or propagating brush discharges, but could be capable of producing cone discharges across the half-width of the bag. Per IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, Type D FIBCs are permitted to be used for Zone Group IIA and IIB gases but not Group IIC. [**652:**A.9.4.7.4.5]

N **A.9.4.3.6.5.1** Type D bags function by corona discharge. Metals or other conductive particulate solids could require additional precautions because, if the particulate is isolated and becomes charged, incendiary sparks could occur during rapid filling and emptying operations. IEC TS 60079-32-1 gives guidance on additional precautions that could be necessary. A risk assessment referencing IEC TS 60079-32-1 could be performed to support the use of Type D FIBCs for conductive particulate solids. [**652:**A.9.4.7.4.5.1]

A.9.4.3.6.6 Table A.9.4.3.6.6 and Figure A.9.4.3.6.6 provide guides for the selection and use of FIBCs based on the MIE of product contained in the FIBC and the nature of the atmosphere surrounding it.

Δ **Table A.9.4.3.6.6 Use of Different Types of FIBCs**

Bulk Product in FIBC	Surroundings		
MIE of Solids[a]	Nonflammable Atmosphere	Class II, Divisions 1 and 2 (1000 mJ ≥ MIE > 3 mJ)[a]	Class I, Divisions 1 and 2 (Gas Group C and D) or Class II, Divisions 1 and 2 (MIE ≤ 3 mJ)[a]
MIE > 1000 mJ	A, B, C, D	B, C, D	C, D[b]
1000 mJ ≥ MIE > 3 mJ	B, C, D	B, C, D	C, D[b]
MIE ≤ 3 mJ	C, D	C, D	C, D[b]

Notes:

(1) Additional precautions usually are necessary when a flammable gas or vapor atmosphere is present inside the FIBC, for example, in the case of solvent wet solids.

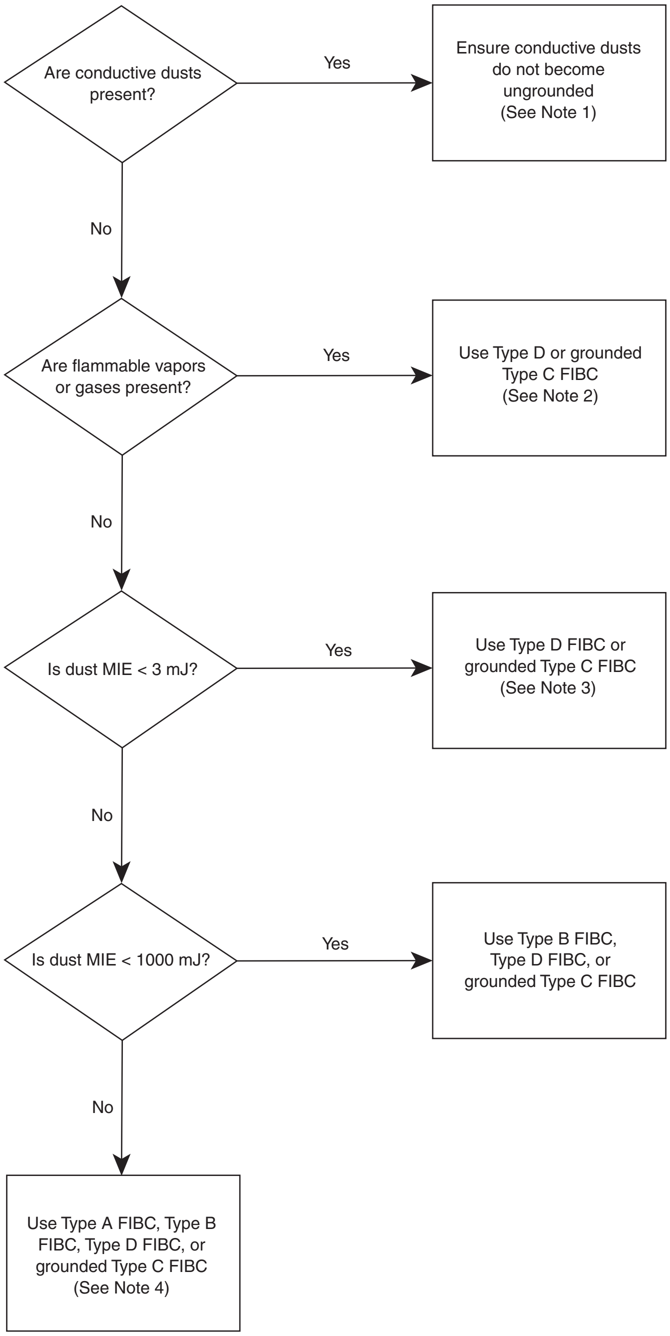
(2) Nonflammable atmosphere includes combustible particulate solids having an MIE greater than 1000 mJ.

(3) FIBC Types A, B, and D are not suitable for use with conductive combustible particulate solids.

[a]Measured in accordance with ASTM E2019, capacitive discharge circuit (no added inductance).

[b]Use of Type C and D is limited to Gas Groups C and D with MIE greater than or equal to 0.14 mJ.

[**652:**Table A.9.4.7.4.6]



Note 1: Conductive dusts can produce spark discharges if allowed to be isolated from ground. Grounded Type C FIBCs can provide adequate grounding, but some Type C FIBCs have internal coatings or liners that can allow conductive dusts to remain isolated. A risk assessment is recommended prior to handling conductive dusts in FIBCs.

Note 2: Do not use Type D FIBCs for flammable vapors/gases with MIE < 0.14 mJ.

Note 3: Type A or B FIBCs can allow cone discharges to occur across the full width of the FIBC, with an effective energy up to 3 mJ.

Note 4: Type A FIBCs have the potential to produce propagating brush discharges with effective energy of ~1000 mJ.

N **FIGURE A.9.4.3.6.6 FIBC Selection Decision Tree. [652:Figure A.9.4.7.4.6]**

N **A.9.4.3.6.6.3** Inner liners for FIBCs are separated into three types. Note that the selection of the type of liner is critical to maintaining classification of the FIBC. Appropriate inner liner selection, where applicable, is addressed in IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications —Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, and Table 20 of IEC 60079-32-1, *Explosive Atmospheres — Part 32-1: Electrostatic Hazards, Guidance*.

Type L1 liners are made from materials with surface resistivity on at least 1 surface of less than 10^7 ohms and, where necessary, a breakdown voltage through the material less than 4 kV. They should be used only with Type C FIBCs, and the liner should be electrically bonded to the conductive elements of the FIBCs.

Type L2 liners are made from materials with surface resistivity on at least 1 surface between 10^9 ohms and 10^{12} ohms and a breakdown voltage through the material less than 4 kV. They should be used with Type B, C, or D FIBCs. When used with Type D FIBCs, the combination of FIBCs and liner should be tested together.

Type L3 liners are made from materials with surface resistivity of greater than 10^{12} ohms and a breakdown voltage through the material less than 4 kV. They should be used only with Type B FIBCs.

Type A FIBCs have no specific requirements for liners, because Type A FIBCs are not appropriate for use in hazardous atmospheres regardless of liner type.

Users should consult an expert or the latest edition of IEC 60079-32-1 to validate proper liner selection.

Δ **A.9.4.3.6.7** In special cases it might be necessary to use a type of FIBC that is not permitted for the intended application based on the requirements of 9.4.3.6. For such cases, it might be determined that the FIBC is safe to use provided that filling or emptying rates are restricted to limit electrostatic charging. In the case of conductive combustible particulate solids, the use of a Type A FIBC might be acceptable provided that the maximum ignition energy from the FIBC or charged product within it is less than the MIE of the combustible particulate solids. [**652:**A.9.4.7.4.7]

A.9.4.3.7.1 Conductive containers are generally made from either metal or carbon-filled plastic having a volume resistivity less than 10^6 ohm-m. [**652:**A.9.4.7.5.1]

Δ **A.9.4.3.7.2** Induction charging of ungrounded conductive objects, including personnel, should be addressed as part of the risk assessment and dust hazards analysis when the use of nonconductive RIBCs is being considered. The risk assessment should also consider that higher rates of transfer into and out of the RIBC increase the rate of charge generation, which could result in the brush discharges, propagating brush discharges, or surface (cone) discharges while the RIBC is being filled. For additional information on these phenomena, refer to NFPA 77. [**652:**A.9.4.7.5.2]

A.9.4.3.9 See NFPA 77 for recommended practices on manual additions of solids into vessels containing flammable atmospheres, including recommended practices on the grounding of personnel.

A.9.4.3.9.1 For example, metal chimes on fiber drums should be grounded. For uncoated fiber drums, grounding one chime might be sufficient. Where contact with a grounded operator is used to ground the container (such as with static-dissipative bags), it is important that gloves, if used, be static-dissipative and free of contaminants.

A.9.4.3.9.4 Examples of auxiliary loading devices include shovels, scoops, and funnels. Conductive tools can be grounded through a properly grounded operator. See also A.9.4.3.9.1 for guidance related to grounding of containers.

A.9.4.3.9.5 Where static-dissipative footwear is used for personnel grounding, the floor resistance to ground should be between 10^6 and 10^9 ohms. Care should be taken to ensure that deposits, residues, and coatings that build up over time do not impair grounding between the floor and personnel.

A.9.4.3.9.7 A risk assessment should address considerations such as container construction, properties of the solids, properties of the liquid, addition rate, material construction of the receiving vessel, agitating devices, and intensity of agitation. The risk assessment should identify the necessary engineering and administrative controls to ensure that the potential charge accumulation during dumping of the contents will not produce a discharge that exceeds the MIE of the flammable atmosphere within the vessel.

N **A.9.4.3.10** NFPA 77 provides guidance on how to ground personnel. The most common methods of personnel grounding are through conductive flooring and static-dissipative footwear or through dedicated personnel-grounding devices such as wrist straps. Grounding devices should provide a resistance to ground between 10^6 and 10^8 ohms. The lower resistance limit (10^6 ohms) is specified to protect personnel from electrocution due to inadvertent contact with energized electrical equipment, while the upper resistance limit (10^8 ohms) is specified to ensure adequate charge dissipation. Grounding devices should be tested regularly, and cleaning should be performed to ensure that accumulations of nonconductive residues do not interfere with continuity.

N **A.9.4.3.10.1** The user should expect that activities such as pouring, unloading, and transferring dusts can lead to the development of an ignitible atmosphere above the settled material in the receiving vessel. [**652:**A.9.4.7.3.1]

Refer to NFPA 77 for recommendations for how to safely ground personnel. [**652:**A.9.4.7.3.1]

N **A.9.4.3.10.2(2)** Based on information in Britton, *Avoiding Static Ignition Hazards in Chemical Operations*, the maximum reasonable discharge energy from a person is estimated to be approximately 25 mJ. Where the MIE of the dust cloud is greater than 30 mJ, personnel grounding provides no risk reduction. MIE is dependent on particle size, so it is important to determine the MIE value on the particle size distribution that is likely to remain airborne during the operation. Since large particles will quickly fall out of suspension, the sub-75 μ fraction of the material (or material passing through a 200-mesh sieve) is typically tested for this purpose. Where a bulk material includes larger particles, the sub-75 μ MIE might be significantly lower than the bulk material MIE. ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, is the test method for determining particulate and dust MIE. [**652:**A.9.4.7.3.2(2)]

A.9.4.6.1 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.9.4.7 This section does not apply to electrical equipment; that topic is addressed in 9.4.2.2. Dust layer and dust cloud ignition temperatures should be determined by ASTM E2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers*; ASTM E1491, *Standard Test Method for Minimum Autoignition Temperature of Dust Clouds*; or other recognized test methods acceptable to the AHJ. Normally the minimum ignition temperature of a layer of a specific dust is lower than the minimum ignition temperature of a cloud of that dust; however, this is not universally true *(see NFPA 499)*. The minimum ignition temperature typically decreases with increasing layer thickness, and testing up to maximum layer thickness to be expected on external surfaces is recommended.

The ignition temperature of a layer of dust on hot surfaces could decrease over time if the dust dehydrates or carbonizes. For organic dusts that can dehydrate or carbonize, the temperature 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.

A.9.4.8.2 Diesel-powered front-end loaders suitable for use in hazardous locations have not been commercially available. The following provisions can be used to reduce the fire hazard from diesel-powered front-end loaders used in Class II hazardous areas as defined in Article 500 of *NFPA 70*.

(1) Only essential electrical equipment should be used, and wiring should be in metal conduit. Air-operated starting is preferred, but batteries are permitted to be used if they are mounted in enclosures rated for Type EX hazardous areas.
(2) Where practical, a water-cooled manifold and muffler should be used.
(3) Loaders that are certified to meet the Mine Safety and Health Administration (MSHA) criteria (formerly Schedule 31) found in 30 CFR 36, "Approved Requirements for Permissible Mobile Diesel-Powered Transportation Equipment," are also acceptable in lieu of A.9.4.8.2(1) and A.9.4.8.2(2).
(4) The engine and hydraulic oil compartments should be protected with fixed, automatic dry-chemical extinguishing systems.
(5) Loaders should have a high degree of maintenance and cleaning. Frequent cleaning (daily in some cases) of the engine compartment with compressed air could be necessary. Periodic steam cleaning also should be done.
(6) Loaders should never be parked or left unattended in the dust explosion hazard or dust fire hazard area.

A.9.7.1.1(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 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.9.7.1.1(2) Where deflagration venting is used, its design should be based on information contained in NFPA 68. 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.9.7.1.1(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.9.7.1.1(6) For information on dust retention and flame-arresting devices, see NFPA 68, Section 9.7.

A.9.7.2 Methods of explosion protection that use containment, venting, and suppression protect the specific process equipment on which they are installed. For details on deflagration propagation, see Annex E.

Exposures of concern include, but are not limited to, bagging operations and hand-dumping operations in which the discharge of a fireball from the pickup point endangers personnel. A common example for the application of such isolation would be in the upstream ductwork associated with a dust collection system servicing a work area. Loading chutes less than 10 ft (3 m) in length and designed for gravity flow are not considered ductwork.

Δ **A.9.7.2.1** The requirement of 9.7.2.1 might not be applicable where all of the following conditions are met:

(1) The material being conveyed is not a metal dust, ST-3 dust (K_{St} > 300 bar-m/s), or hybrid mixture.
(2) The connecting ductwork is smaller than 4 in. (100 mm) nominal diameter and greater than 15 ft (5 m) in length
(3) The conveying velocity is sufficient to prevent accumulation of combustible dust in the duct.
(4) All connected equipment is properly designed for explosion protection by means other than deflagration pressure containment.
(5) The upstream work areas do not contain large quantities of dust that can be entrained by a pressure pulse from an explosion in the AMS.

Where managing the hazard of propagation via a small duct, performance equivalent alternatives can be developed in accordance with Chapter 6 or 9.3.1.3.

Flame spread via propagation inside ducting or piping is somewhat unpredictable for dusts. Tests have shown that propagation is much less likely under certain conditions. Piping less than 4 in. (100 mm) in diameter is less likely to provide a conduit for flame spread than larger diameter piping, although experiments have shown propagation in still smaller diameter piping.

The FSA conducted flame propagation tests in a system comprising two interconnected, vented 35 ft^3 (1 m^3) vessels. Experiments were carried out with pipe diameters of 1.1 in. (27 mm), 1.6 in. (42 mm), and 3.2 in. (82 mm) [all less than 4 in. (102 mm)]. Corn starch (K_{St} = 200 bar.m/s) and wheat flour (K_{St} ~ 100 bar.m/s) were used as fuels. Even with a small pipe diameter of 1.1 in. (27 mm) and with wheat flour (K_{St} ~ 100 bar.m/s) used as test dust, there was a flame propagation through a pipe length of at least 39 ft (12 m) in length.

For interconnected vessels that are relatively close together, measures to reduce P_{red} for each interconnected vessel, taking into account that propagation could occur, would eliminate the need for isolation techniques.

Dense phase pneumatic transfer [i.e., air velocities down near 600 fpm (183 m/min), and solids loading ratios greater than 30] is also much less likely to provide a conduit for flame spread propagation than for dilute phase pneumatic transfer [i.e., air velocities in the region of 2200 fpm to 3600 fpm (672 m/min to 1098 m/min), and solids loading ratios not greater than 15]. It has been reported by Pineau that it is not uncommon for propagation to occur as few as one time in ten in controlled experiments for 5.9 in. (150 mm) piping even for dilute phase systems. However, recent testing has shown that propagation is more likely with dust concentrations in the lean region. Metal dusts are more likely to propagate deflagrations. For organic dusts, where small diameter pipes with dense phase transfer are utilized, the need for isolation techniques could be obviated if the hazard analysis is acceptable to the AHJ.

Factors for evaluation of isolation between equipment and work areas include, among others, the anticipated P_{red} for the related process equipment, the diameter and length of the connecting air duct, and the quantity of dust in the work area that can be entrained by a pressure pulse from a deflagration in the related process equipment.

See G.1.2.11 for additional information.

A.9.8.3.2.1 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.9.8.3.2.10 Abort gates cannot be relied upon to manage deflagrations. See also Annex C.

A.9.8.3.2.10.1(C) The abort gate should be a high-speed device with a combined reaction time, including detection and closure, of less than 500 milliseconds.

A.9.8.3.2.10.2(B) A powered reset is acceptable if it can only be activated manually at the damper.

A.9.8.3.3.2 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 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.9.2.1.3.1)*, 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.9.8.3.4.2.1 A nozzle listed or approved for use on Class C fires produces a fog discharge pattern that is less likely than a straight stream nozzle to suspend combustible dust, which could otherwise produce a dust explosion potential.

A.9.8.3.4.2.2 Fire responders should be cautioned when using straight stream nozzles in the vicinity of combustible dust accumulations that dust clouds can be formed and can be ignited by any residual smoldering or fire.

A.9.8.3.5 Automatic sprinkler protection in AMSs, 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.9.8.3.5.1 A risk assessment 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 AMS, silos, and bucket elevators should be considered.

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 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

Δ **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.)*

The purge gas flow and oxygen concentration in the process should be designed reliably with appropriate safety factors in accordance with NFPA 69. 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.

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.

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.

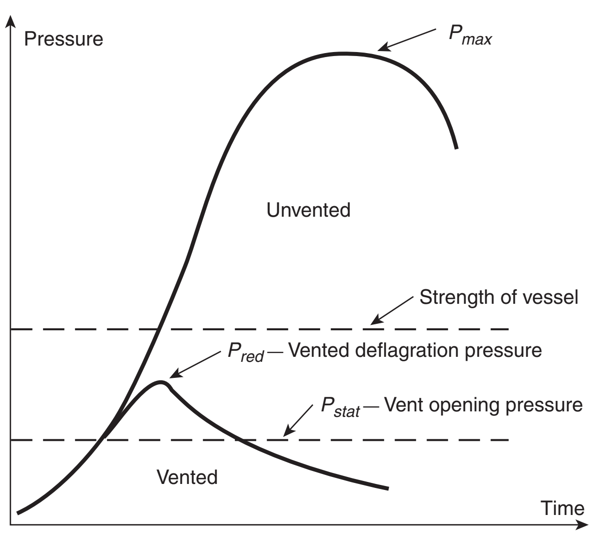


FIGURE B.4.1 Pressure–Time Graph of a Vented Deflagration.

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 air-material separators, 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:

(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

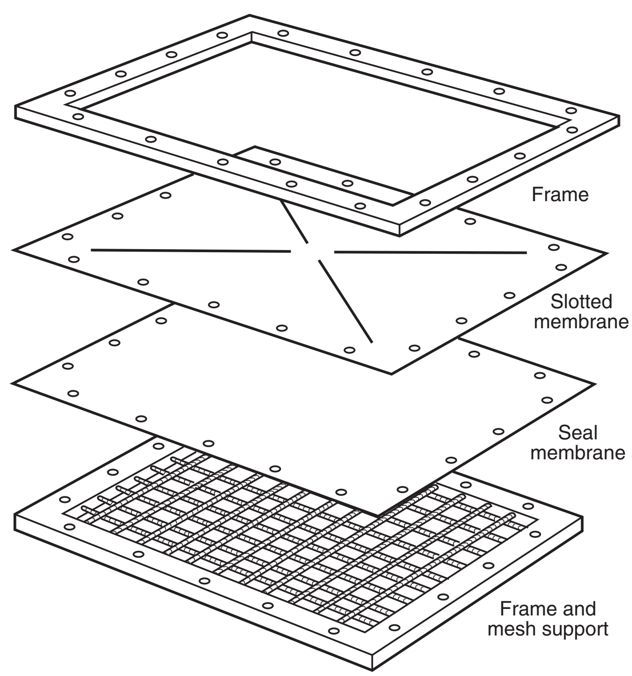


FIGURE B.4.2 Deflagration Vent Panel and Support Grid.

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.

B.5.2 Applications. Deflagration suppression systems are used for applications that handle gases, dusts, or hybrid mixtures. Typical applications include air-material separators, 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

B.5.3 Design Criteria. Deflagration suppression systems are designed in accordance with NFPA 69 and ISO 6184-4, *Explosion protection systems — Part 4: Determination of efficiency of explosion suppression systems*. The following information is required 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, 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:**A.8.12]

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

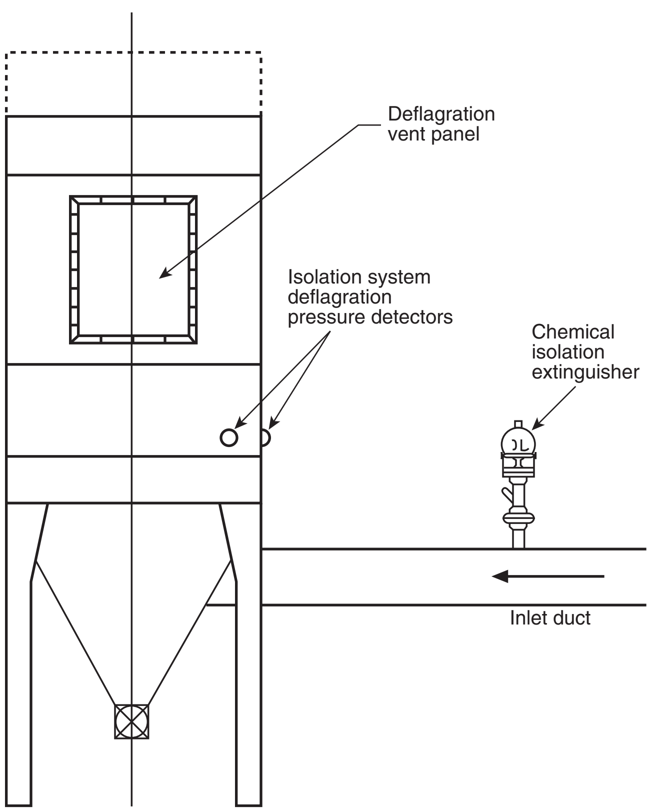


FIGURE B.4.4 Vented Dust Collector.

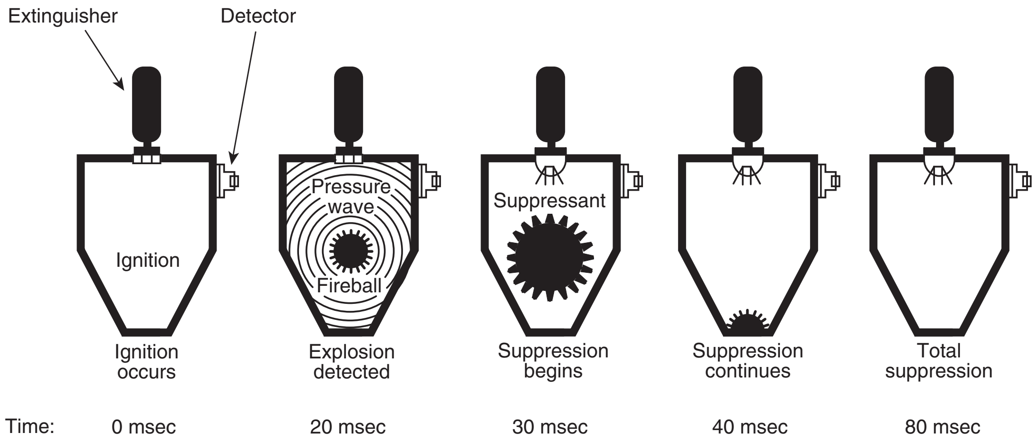


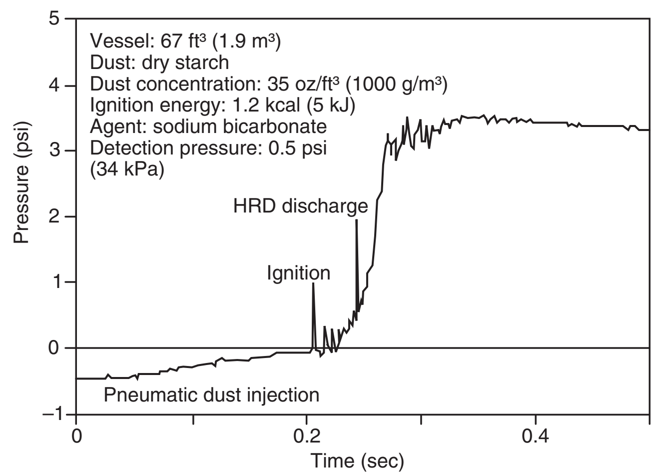
FIGURE B.5.1(a) Deflagration Suppression Sequence of Starch in a 35 ft^3 (1 m^3) Vessel.

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.

Δ **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.



Note: Pressures are gauge pressures.

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

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.

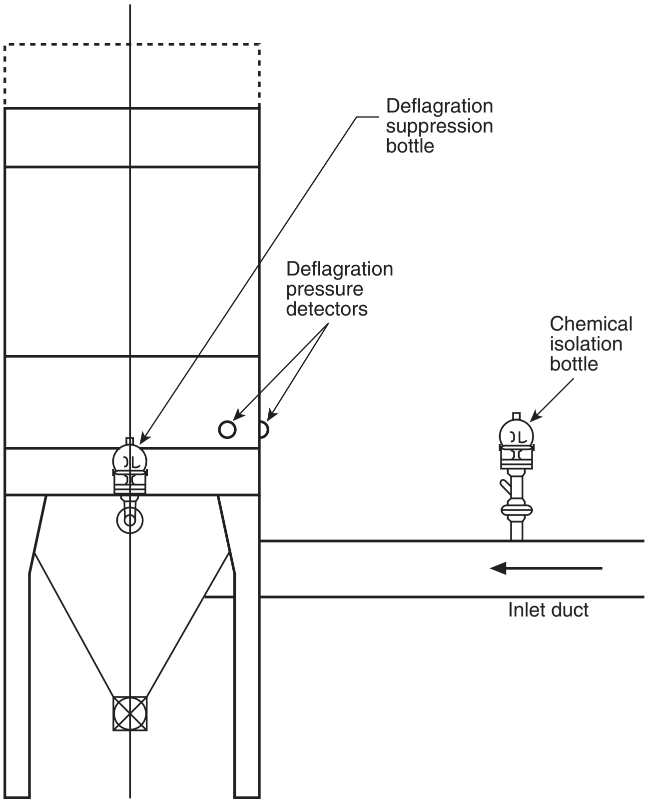


FIGURE B.5.2 Dust Collector Suppression System.

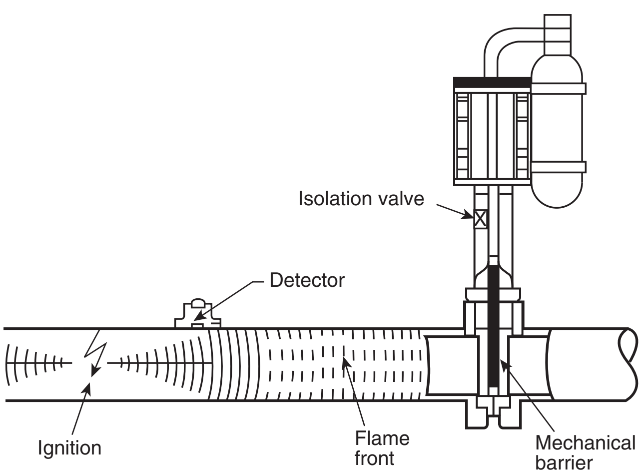


FIGURE B.6.1 Mechanical Isolation Using a High-Speed Gate Valve.

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 AMD is located downstream of the flame front 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

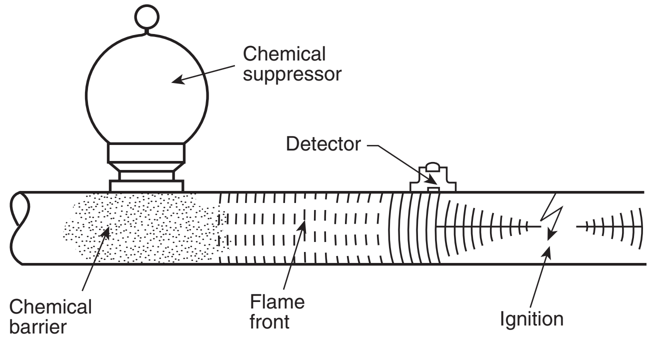


FIGURE B.6.2 Typical Arrangement of Chemical Isolation.

vapors exceed the LFL, regardless of the location of the AMD. 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*. 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 and maintained pursuant to NFPA 25. 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.

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 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.

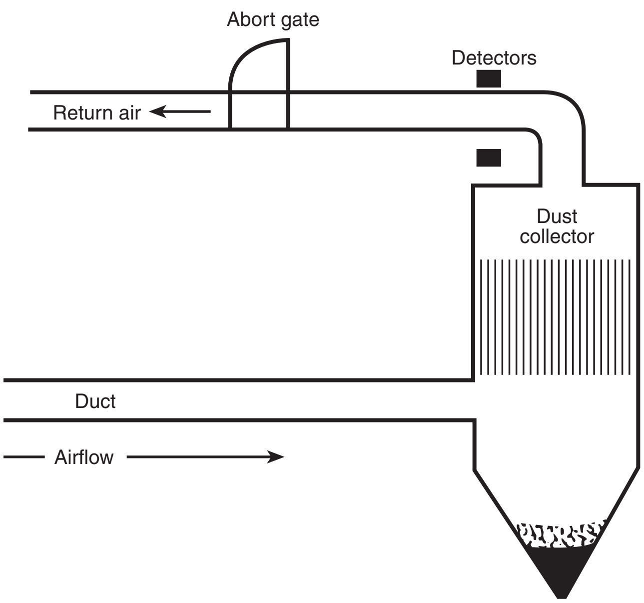


FIGURE C.1.1.1 Spark Detectors and Abort Gate.

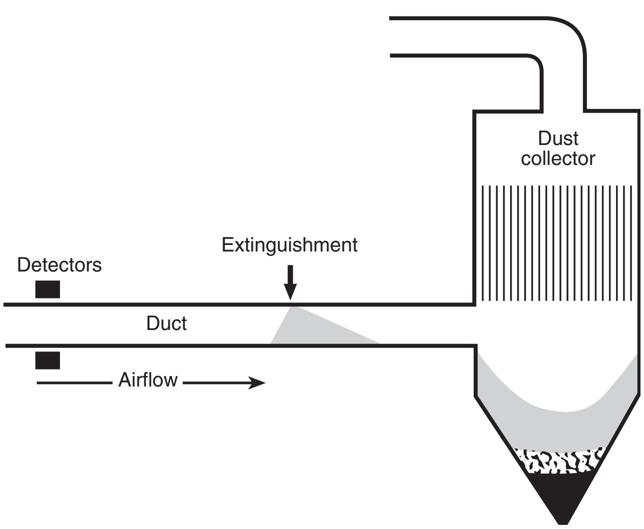


FIGURE C.1.1.2 Typical Spark Detection and Extinguishing System.

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* 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.

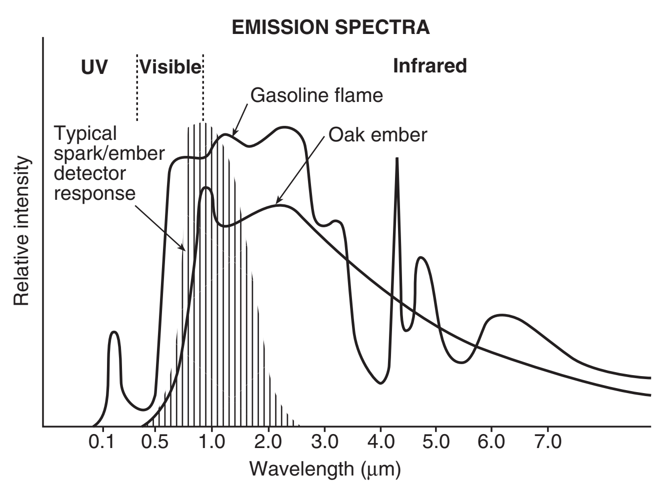


FIGURE C.1.2.1 Emissions of an Oak Ember and Gasoline Flame Compared to the Spectral Sensitivity of a Spark/Ember Detector.