NFPA 654

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

2000 Edition

NFPA, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

IMPORTANT NOTICE ABOUT THIS DOCUMENT

NFPA codes, standards, recommended practices, and guides, of which the document contained herein is one, are developed through a consensus standards development process approved by the American National Standards Institute. This process brings together volunteers representing varied viewpoints and interests to achieve consensus on fire and other safety issues. While the NFPA administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in its codes and standards.

The NFPA disclaims liability for any personal injury, property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this document. The NFPA also makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

In issuing and making this document available, the NFPA is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the NFPA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

The NFPA has no power, nor does it undertake, to police or enforce compliance with the contents of this document. Nor does the NFPA list, certify, test or inspect products, designs, or installations for compliance with this document. Any certification or other statement of compliance with the requirements of this document shall not be attributable to the NFPA and is solely the responsibility of the certifier or maker of the statement.

See inside back cover for additional important notices and information.

NOTICES

All questions or other communications relating to this document and all requests for information on NFPA procedures governing its codes and standards development process, including information on the procedures for requesting Formal Interpretations, for proposing Tentative Interim Amendments, and for proposing revisions to NFPA documents during regular revision cycles, should be sent to NFPA headquarters, addressed to the attention of the Secretary, Standards Council, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

Users of this document should be aware that this document may be amended from time to time through the issuance of Tentative Interim Amendments, and that an official NFPA document at any point in time consists of the current edition of the document together with any Tentative Interim Amendments then in effect. In order to determine whether this document is the current edition and whether it has been amended through the issuance of Tentative Interim Amendments, consult appropriate NFPA publications such as the *National Fire Codes*® Subscription Service, visit the NFPA website at www.nfpa.org, or contact the NFPA at the address listed above.

A statement, written or oral, that is not processed in accordance with Section 6 of the Regulations Governing Committee Projects shall not be considered the official position of NFPA or any of its Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

The NFPA does not take any position with respect to the validity of any patent rights asserted in connection with any items which are mentioned in or are the subject of this document, and the NFPA disclaims liability for the infringement of any patent resulting from the use of or reliance on this document. Users of this document are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Users of this document should consult applicable federal, state, and local laws and regulations. NFPA does not, by the publication of this document, intend to urge action that is not in compliance with applicable laws, and this document may not be construed as doing so.

Licensing Policy

This document is copyrighted by the National Fire Protection Association (NFPA). By making this document available for use and adoption by public authorities and others, the NFPA does not waive any rights in copyright to this document.

1. Adoption by Reference—Public authorities and others are urged to reference this document in laws, ordinances, regulations, administrative orders, or similar instruments. Any deletions, additions, and changes desired by the adopting authority must be noted separately. Those using this method are requested to notify the NFPA (Attention: Secretary, Standards Council) in writing of such use. The term "adoption by reference" means the citing of title and publishing information only.

2. Adoption by Transcription—A. Public authorities with lawmaking or rule-making powers only, upon written notice to the NFPA (Attention: Secretary, Standards Council), will be granted a royalty-free license to print and republish this document in whole or in part, with changes and additions, if any, noted separately, in laws, ordinances, regulations, administrative orders, or similar instruments having the force of law, provided that: (1) due notice of NFPA's copyright is contained in each law and in each copy thereof; and (2) that such printing and republication is limited to numbers sufficient to satisfy the jurisdiction's lawmaking or rule-making process. **B.** Once this NFPA Code or Standard has been adopted into law, all printings of this document by public authorities with lawmaking or rule-making powers or any other persons desiring to reproduce this document or its contents as adopted by the jurisdiction in whole or in part, in any form, upon written request to NFPA (Attention: Secretary, Standards Council), will be granted a nonexclusive license to print, republish, and vend this document in whole or in part, with changes and additions, if any, noted separately, provided that due notice of NFPA's copyright is contained in each copy. Such license shall be granted only upon agreement to pay NFPA a royalty. This royalty is required to provide funds for the research and development necessary to continue the work of NFPA and its volunteers in continually updating and revising NFPA standards. Under certain circumstances, public authorities with lawmaking or rule-making powers may apply for and may receive a special royalty where the public interest will be served thereby.

3. Scope of License Grant—The terms and conditions set forth above do not extend to the index of this document.

(For further explanation, see the Policy Concerning the Adoption, Printing, and Publication of NFPA Documents, which is available upon request from the NFPA.)

NFPA 654

Standard for the

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

2000 Edition

This edition of NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, was prepared by the Technical Committee on Handling and Conveying of Dusts, Vapors, and Gases and acted on by the National Fire Protection Association, Inc., at its World Fire Safety Congress and Exposition™ held May 14–17, 2000, in Denver, CO. It was issued by the Standards Council on July 20, 2000, with an effective date of August 18, 2000, and supersedes all previous editions.

This edition of NFPA 654 was approved as an American National Standard on August 18, 2000.

Origin and Development of NFPA 654

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

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

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

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

For the 1997 edition, the committee completely revised the standard to incorporate new processing and explosion protection technologies. The title of the document was revised to reflect that the standard 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.

For the 2000 edition, the committee completely revised the standard to incorporate portions of NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Particulate Solids*, which has been withdrawn. NFPA 654 retains its title and now provides a unified approach for protecting facilities handling most combustible particulate solids. The combination of documents eliminates redundancy that previously existed between the two similar standards. This new edition includes specific requirements related to fire protection in addition to the existing explosion protection requirements.

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

Murray A. Cappers, Jr., *Chair*
Marsh USA, Inc., NJ [I]

Joe R. Barton, Indianapolis, IN [U]
Kris Chatrathi, Fike Corp., MO [M]
John M. Cholin, J M Cholin Consultants Inc., NJ [SE]
David G. Clark, The DuPont Co., DE [U]
Ralph E. Collins, R E Collins Assoc., MA [SE]
C. James Dahn, Safety Consulting Engineers Inc., IL [SE]
Vahid Ebadat, Chilworth Technology Inc., NJ [SE]
Walter L. Frank, EQE Int'l, Inc., DE [U]
Henry W. Garzia, Fenwal Safety Systems/Williams Holdings, MA [M]
Ray E. George, The Chemithon Corp., WA [M]
Joseph P. Gillis, Westboro, MA [SE]
Ray Hunter, Ray Hunter & Assoc. Inc., AL [M]
Rep. American Air Filter
Jerry J. Jennett, Georgia Gulf Sulfur Corp., GA [M]
David C. Kirby, Union Carbide Corp., WV [M]
James E. Maness, Bunge Corp., MO [U]
Rep. Grain Elevator & Processing Society
Guillermo A. Navas, Sheet Metal & Air Conditioning Contractors' Nat'l Assn., VA [M]
Robert W. Nelson, Pocasset, MA [I]
Rep. HSB Industrial Risk Insurers
James L. Roberts, Fluor Daniel, Inc., SC [SE]
Richard F. Schwab, AlliedSignal Inc., NJ [U]
William J. Stevenson, Cv Technology, Inc., FL [M]
Lynn K. Underwood, Wausau HPR Engineering, WI [I]
John Valiulis, FM Global, MA [I]
Harold H. Weber, Jr., The Sulphur Inst., DC [U]
(Vote Ltd. to 655)
W. H. White, White Consulting Services, OH [SE]
Rep. TC on Finishing Processes

Alternates

Ted Brown, Int'l Sulphur, Inc., TX [M]
(Alt. to J. J. Jennett)
Henry L. Febo, Jr., FM Global, MA [I]
(Alt. to J. Valiulis)
Paul F. Hart, HSB Industrial Risk Insurers, IL [I]
(Alt. to R. W. Nelson)
Gregory I. Hurst, Nat'l Starch & Chemical Co., IN [U]
(Alt. to J. R. Barton)
Robert A. Koehler, Wausau HPR Engineering, TX [I]
(Alt. to L. K. Underwood)
Bernadette N. Reyes, Safety Consulting Engineers, Inc., IL [SE]
(Alt. to C. J. Dahn)
John H. Stratton, Sheet Metal & Air Conditioning Contractors' Nat'l Assn., VA [M]
(Alt. to G. A. Navas)

Nonvoting

Harry Verakis, U.S. Dept. of Labor, Mine Safety & Health Admin., WV

Guy R. Colonna, NFPA Staff Liaison

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

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

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

2000 Edition

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

A reference in parentheses ( ) following a section or paragraph indicates material that has been extracted from another NFPA document. The complete title and edition of the document the material is extracted from is found in Chapter 9. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. Requests for interpretations or revisions of extracted text shall be sent to the appropriate technical committee.

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

Chapter 1 General

1.1 Scope.

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

1.1.2 This standard shall apply to systems that convey combustible particulate solids that are produced as a result of a principal or incidental activity, regardless of concentration or particle size, where the materials present a fire or explosion hazard.

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

(1) NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*
(2) NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Products Facilities*
(3) NFPA 120, *Standard for Coal Preparation Plants*
(4) NFPA 432, *Code for the Storage of Organic Peroxide Formulations*
(5) NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*
(6) NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium*
(7) NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*
(8) NFPA 485, *Standard for the Storage, Handling, Processing, and Use of Lithium Metal*
(9) NFPA 495, *Explosive Materials Code*
(10) NFPA 651, *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders*
(11) NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*
(12) NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*
(13) NFPA 1124, *Code for the Manufacture, Transportation, and Storage of Fireworks and Pyrotechnic Articles*
(14) NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*
(15) NFPA 8503, *Standard for Pulverized Fuel Systems*

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

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

1.3 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. Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency. The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.4 Retroactivity.

1.4.1 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.

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.

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.

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.

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

1.5 Definitions. For the purposes of this standard, the following terms and definitions shall apply.

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

1.5.2* Air–Material Separator (AMS). Any device designed to separate the conveying air from the material being conveyed.

1.5.2.1 Primary Air–Material Separator. A collector that removes the bulk of the product or material from the conveying air stream.

1.5.2.2 Secondary Air–Material Separator. A device for removing the residual dust or product remaining in the air stream after the primary air–material separator.

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

1.5.4* Approved. Acceptable to the authority having jurisdiction.

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

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

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

1.5.8 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.

1.5.9 Deflagration. Propagation of a combustion zone through a fuel–oxidizer mixture at a rate that is less than the speed of sound in the unreacted medium and capable of producing a significant increase in pressure.

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

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

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

1.5.13 Dust Collector. See definition 1.5.2, Air–Material Separator.

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

1.5.15 Fire Barrier Wall. A wall separating buildings or subdividing a building to prevent the spread of fire and having a fire resistance rating and structural stability.

1.5.16 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.

1.5.17* Hybrid Mixture. A mixture of air and combustibles that contains combustibles of different physical states.

1.5.18 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.

1.5.19* 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.

1.5.20* 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.

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

1.5.22* 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.

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

1.5.23.1* Negative-Pressure Pneumatic Conveying System. Systems that transport material by utilizing gas at less than atmospheric pressure.

1.5.23.2* Positive-Pressure Pneumatic Conveying System. Systems that transport material by utilizing gas at greater than atmospheric pressure.

1.5.24 Replace-in-Kind. To furnish with new parts or equipment, as applied to equipment and facilities, of the same type but not necessarily of identical design.

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

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

1.5.27 Shall. Indicates a mandatory requirement.

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

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

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

1.5.31 Vent Closure. A pressure-relieving cover that is placed over a vent.

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

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

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

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

Chapter 2 Facility and Systems Design

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

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

2.1.2 The design of systems and facilities that handle combustible particulate solids shall consider the physical and chemical properties and hazardous characteristics of the materials being conveyed.

2.1.2.1 Those portions of the process and facility where dust explosion hazards exist shall be protected from the effects of dust explosions in accordance with Sections 2.2, 2.3, 2.4, and Chapter 3.

2.1.2.2 Those portions of the process and facility where a combustible particulate solid presents a fire hazard shall be protected in accordance with Chapter 6.

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

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

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

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

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

2.1.6* The design and its basis shall be documented and shall include the properties that define the hazards of the material being processed.

2.1.7 All components of pneumatic conveying systems that handle combustible particulate solids shall be designed to be dusttight.

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

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

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

2.2.2 Use of Segregation.

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

2.2.2.2 Physical barriers that are erected to segregate dust deflagration hazards shall be designed to preclude failure of these barriers before the deflagration pressure can be safely vented to the outside. (For deflagration venting, see Section 2.4.)

2.2.3 Use of Separation.

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

Exception: For dust accumulations with a bulk density less than 75 lb/ft³ (33.75 kg/m³), the allowable thickness can be prorated upward by the following equation:

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

2.2.3.2 The required separation distance between the hazardous area identified in 2.2.3.1 and surrounding exposures shall be determined by an engineering evaluation that addresses the properties of the materials, the type of operation, the amount of material likely to be present outside the process equipment, the building design, and the nature of surrounding exposures. In no case shall the distance be less than 30 ft (9 m).

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

2.3 Building Construction.

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

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

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

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

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

2.3.6 Means of egress shall comply with NFPA *101*®, *Life Safety Code*®.

2.3.7 All penetrations of floors, walls, ceilings, and partitions shall be dusttight, and, where structural assemblies have a fire endurance rating, the seal shall maintain that rating.

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

2.3.8 Interior stairs, elevators, and manlifts shall be enclosed in dusttight shafts that have a minimum fire resistance rating of 1 hour. Doors that are the automatic-closing or self-closing type and have a fire resistance rating of 1 hour shall be provided at each landing.

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

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

2.4* Deflagration Venting.

2.4.1* If a room or building contains a dust explosion hazard that is external to protected equipment, as defined in 2.2.3.1, such areas shall be provided with deflagration venting to a safe outside location.

2.4.2* Vent closures shall be directed toward a restricted area, and the vent closure shall not be a missile hazard. The fireball and blast pressure that are created by the venting process shall not impinge upon unrestricted personnel pathways.

2.5* Relief Valves. Relief valves shall not be vented to a dust hazard area as defined by 2.2.3.1.

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

2.7 Electrical Equipment.

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

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

2.7.3 Hazardous (classified) areas that are identified in accordance with 2.7.2 shall be documented, and such documentation shall be permanently maintained on file for the life of the facility.

2.8 Management of Change. Written procedures to manage change to process materials, technology, equipment, procedures, and facilities shall be established and implemented. The requirements of 2.8.1 through 2.8.2 shall be applied retroactively.

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

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

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

2.8.2 Design documentation, as required by 2.1.6, shall be updated to incorporate the change.

Chapter 3 Process Equipment

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

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

3.1.1 Explosion Protection for Equipment. The design of explosion protection for equipment shall incorporate one or more of the following methods of protection:

(1) Oxidant concentration reduction in accordance with NFPA 69, *Standard on Explosion Prevention Systems*
  a. Where oxygen monitoring is used, it shall be installed in accordance with ISA S84.01, *Application of Safety Instrumented Systems for the Process Industries.*
  b.*When the chemical properties of the material being conveyed require a minimum concentration of oxygen to control pyrophoricity, that level of concentration shall be maintained.
(2)* Deflagration venting
(3) Deflagration pressure containment in accordance with NFPA 69, *Standard on Explosion Prevention Systems*
(4) Deflagration suppression systems in accordance with NFPA 69, *Standard on Explosion Prevention Systems*
(5)* Dilution with a noncombustible dust to render the mixture noncombustible. If this method is used, test data for specific dust and diluent combinations shall be provided and shall be acceptable to the authority having jurisdiction.
(6) Deflagration venting through a listed dust retention and flame-arresting device

3.1.2 Fire Protection for Equipment. Equipment fire protection shall be designed in accordance with Chapter 6.

3.1.3* Isolation of Equipment.

3.1.3.1 Where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between pieces of equipment connected by ductwork. Isolation devices include, but are not limited to, the following:

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

Exception No. 1: Isolation devices are not required when oxidant concentration has been reduced or when the dust has been rendered noncombustible in accordance with 3.1.1(1) or (5).

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

3.1.3.2* Where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation from air–material separators upstream to the work areas. Isolation devices include, but are not limited to, those listed in 3.1.3.1(1) through (5).

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

3.1.3.3 Where a fire propagation hazard exists, the requirements of Chapter 6 shall apply.

3.2 Bulk Storage Enclosures.

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

Exception: The requirements of this section do not apply to containers that are used for transportation of the material.*

3.2.2 Construction. Bulk storage containers, whether located inside or outside of buildings, shall be constructed of noncombustible material.

3.2.3 Explosion Hazards.

3.2.3.1 Where an explosion hazard exists, there shall be no intertank or interbin venting.

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

Exception No. 1: Those fixed bulk storage containers that are protected in accordance with 3.1.1(1), (3), (4), (5), or (6).

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

Exception No. 3: Fixed bulk storage containers of 8 ft^3 (0.2 m^3) or less.*

3.2.3.3 Where an explosion hazard exists, fixed bulk storage containers shall be protected in accordance with 3.1.1.

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

Exception No. 2: Explosion protection requirements per 3.1.1 shall be permitted to be omitted if the volume of the fixed bulk storage container is less than 8 ft^3 (0.2 m^3).*

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

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

3.2.5* Access Doors and Openings.

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

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

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

3.2.5.4 Access doors shall be properly bonded and grounded.

3.3 Material Transfer System.

3.3.1 General.

3.3.1.1 Where more than one material is to be handled by a system, compatibility tests shall be run. Where incompatibility is found, provisions shall be made for cleaning the system prior to transporting a new material.

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

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

3.3.2 Pneumatic Conveying Systems.

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

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

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

3.3.2.4 The design of the pneumatic conveyance system shall be documented. The documentation shall include the following:

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

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

3.3.3 Operations.

3.3.3.1 Sequence of Operation. Pneumatic conveying systems shall be designed with the operating logic, sequencing, and timing outlined in 3.3.3.2 and 3.3.3.3.

3.3.3.2* Start-Up. Pneumatic conveying systems shall be designed such that, upon start-up, the system will achieve and maintain design air velocity prior to the admission of material to the system.

3.3.3.3 Shutdown. Pneumatic conveying systems shall be designed such that, upon shutdown of the process, the system will maintain design air velocity until material is purged from the system.

3.4 Specific Requirements for Systems That Convey Metal Particulates.

3.4.1 General. This section shall apply to facilities that operate pneumatic conveying systems for metallic particulates.

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

Exception No. 1: Specially engineered high-density water spray systems approved by the authority having jurisdiction shall be permitted to be used.

Exception No. 2: This requirement shall not apply to the collection of iron dusts from shot blasting.

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

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

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.

Exception: Systems protected in accordance with 3.1.1(1), (2), (3), and (4).

3.6 Duct Systems.

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

3.6.2 Flexible hose and connections shall be permitted to be used for material pickup and isolation. Bellows shall be permitted to be used for the free movement of weigh bins if the bellows are conductive and the equipment is bonded and grounded.

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

3.6.4* 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.

3.7 Sight Glasses.

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

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

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

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

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

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

3.8 Pressure Protection Systems.

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

3.8.2* Pressure Relief Devices. Pressure relief devices for relief of pneumatic overpressure shall be installed on positive-pressure systems.

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

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

3.8.3 Airflow Control Valves.

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

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

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

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.

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.

3.9 Material Feeding Devices.

3.9.1 Mechanical Feeding Devices. Mechanical feeding devices shall be equipped with a shear pin or overload detection device and alarm. The alarm shall sound at the operator control station.

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

Exception: Belt, chain and sprocket, or other indirect drives 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.

3.10* Bucket Elevators.

3.10.1* Where an explosion hazard exists, bucket elevators shall be provided with deflagration venting. When bucket elevators are located within the building, deflagration vents shall be ducted to the outside.

Exception: As an alternative to deflagration venting, bucket elevators shall be permitted to be protected in accordance with 3.1.1(1), (3), (4), (5), (6) or 3.1.3.1(5).

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

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

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

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

3.10.6 No bearings shall be located within the bucket elevator casing.

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

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

3.10.9 Elevators shall have monitors at head and tail pulleys that indicate high bearing temperature, vibration detection, head pulley alignment, and belt alignment. Abnormal conditions shall actuate an alarm requiring corrective action. The alarm shall sound at the operator control station.

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

3.10.10 All bins into which material is directly discharged from the bucket elevator and that are not designed with automatic overflow systems shall be equipped with devices to shut down equipment or with high-level indicating devices with visual or audible alarms. The alarm shall sound at the operator control station.

3.11* Enclosed Conveyors.

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

3.11.2 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. The alarm shall sound at the operator control station. Feed to the conveyor shall be stopped or diverted.

3.12 Air-Moving Devices (Fans and Blowers).

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

3.12.2 Where an explosion hazard exists, systems shall be designed in such a manner that combustible material does not pass through an air-moving device.

Exception No. 1: Those systems designed to operate at a combustible particulate solids concentration or hybrid mixture concentration of less than 0.0003 oz/ft^3 (0.3 gm/m^3).*

Exception No. 2: Those systems operating at a combustible particulate solids concentration or hybrid mixture concentration equal to or greater than 0.0003 oz/ft^3 (0.3 gm/m^3) and 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 any of the following: 3.1.1(1), (4), (5), or 3.1.3.1(3), (4), or (5).*

3.12.3 Where a fire hazard exists and where combustible particulate solids pass through an air-moving device, provisions shall be made to prevent ignited material from entering processes downstream, in accordance with Chapter 6.

3.13 Air–Material Separators (Air-Separation Devices).

3.13.1 General.

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

Exception No. 1: Those air–material separators that are protected in accordance with 3.1.1(1), (3), (4), (5), or (6).

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

Exception No. 3: The requirements of this section shall be permitted to be omitted if the volume of the air–material separator is less than 8 ft^3 (0.2 m^3).

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

3.13.1.3 Air–material separators shall be protected in accordance with 3.1.1.

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

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

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

Exception No. 2: Dust collection ducts from nonassociated pieces of equipment shall be permitted to be manifolded if each of the ducts is equipped with an isolation device prior to manifolding in accordance with 3.1.3.

Exception No. 3: Dust collection ducts for centralized vacuum cleaning systems shall be permitted to be manifolded.

3.13.1.5* Isolation devices shall be provided for air–material separators in accordance with 3.1.3.

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

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

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

Exception No. 2: Air from air–material separators shall be permitted to be returned to the building when in compliance with the requirements of 2.1.3.

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

3.13.2 Construction.

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

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

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

3.13.2.3 Access doors.

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

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

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

3.13.2.3.4 Access doors shall be properly bonded and grounded.

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

3.14 Abort Gates/Abort Dampers.

3.14.1 Construction. Abort gates and abort dampers shall be constructed of noncombustible materials. Abort gates and abort dampers that are installed after January 1, 2004, shall be listed for the purpose.

Exception: This requirement shall not apply to replacement components for abort gates or abort dampers that are installed on or before January 1, 2004.

3.14.2 Operation.

3.14.2.1 The abort gate or abort damper shall be installed so that it diverts airflow to a restricted area.

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

3.15* Size Reduction.

3.15.1 Before material is processed by size reduction equipment, foreign materials shall be removed as required by 5.1.1.

3.15.2 Where an explosion hazard exists, protection shall be provided as specified in 3.1.1.

3.15.3 Where a fire hazard exists, protection shall be provided in accordance with Chapter 6.

3.16* Particle Size Separation.

3.16.1 Particle-separation devices shall be in dusttight enclosures.

3.16.2 Connection ducts shall be in conformance with Section 3.5.

3.16.3* Where an explosion hazard exists, protection shall be provided as specified in 3.1.1.

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

3.16.4 Where a fire hazard exists, protection shall be in accordance with Chapter 6.

3.17 Mixers and Blenders.

3.17.1 Mixers and blenders shall be dusttight.

3.17.2 Foreign materials shall be removed as required by 5.1.1.

3.17.3 Where an explosion hazard exists, protection shall be provided as specified in 3.1.1.

3.17.4 Where a fire hazard exists, protection shall be in accordance with Chapter 6.

3.17.5 Mixers and blenders shall be made of metal or other noncombustible material.

3.18* Dryers.

3.18.1 Heating systems shall be in accordance with Section 5.6.

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

Exception: Drying media, not containing flammable vapor, shall be permitted to be recycled to the drying process if passed through a filter, dust separator, or equivalent means of dust removal.

3.18.3 Dryers shall be constructed of noncombustible materials.

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

3.18.5 Access doors or openings shall be provided in all parts of the dryer and connecting conveyors to permit inspection, cleaning, maintenance, and the effective use of portable extinguishers or hose streams.

3.18.6 Where an explosion hazard exists, protection shall be provided as specified in 3.1.1.

3.18.7 Where a fire hazard exists, protection shall be in accordance with Chapter 6.

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

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

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

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

Chapter 4 Fugitive Dust Control and Housekeeping

4.1 Fugitive Dust Control. Continuous suction shall be provided for processes where combustible dust is liberated in normal operation so as to minimize the escape of dust. The dust shall be conveyed to dust collectors.

4.2 Housekeeping. The requirements of 4.2.1 through 4.2.3 shall be applied retroactively.

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

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

(1) Area and equipment shall be vacuumed prior to blowdown.
(2) Electrical power and other sources of ignition shall be shut down or removed from the area.
(3) Only low gauge pressure [15 psi (103 kPa)] steam or compressed air shall be used.
(4) There shall be no hot surfaces in an area that is capable of igniting a dust cloud or layer.

4.2.3 Vacuum cleaners shall be listed for use in Class II hazardous locations or shall be a fixed-pipe suction system with remotely located exhauster and dust collector installed in conformance with Section 3.13.

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

Chapter 5 Ignition Sources

5.1 Heat from Mechanical Sparks and Friction.

5.1.1 Foreign Materials.

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

5.1.1.2 Floor sweepings shall not be returned to any machine.

5.1.1.3* Where the process is configured such that the pneumatic conveying system conveys materials that can act as an ignition source, means shall be provided to minimize the hazard. These means shall be permitted to include protection measures identified in 3.1.1 and Section 6.1, as appropriate.

5.1.1.4* 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) Magnetic separators of the permanent or electromagnetic type (Where electromagnetic separators are used, provisions shall be made to indicate the loss of power to the electromagnetic separators.)
(2) Pneumatic separators
(3) Grates or other separation devices

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

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

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

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

5.2 Electrical Equipment. All electrical equipment and installations shall comply with the requirements of Section 2.7.

5.3* Static Electricity. The requirements of 5.3.2 and 5.3.3 shall be applied retroactively.

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

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

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

(b) Where materials being conveyed are not compatible with metal ductwork and other means of explosion protection are provided in accordance with 3.1.1(1), (3), (4), or (5).

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

5.3.3 Portable nonconductive bulk containers such as flexible intermediate bulk containers (FIBCs) shall not be permitted to discharge material into equipment where flammable vapor atmospheres or ignition-sensitive dust atmospheres are present.

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

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

Exception: Manual additions of solids through an open port or manway shall be permitted to be done in 50-lb (25-kg) batches or smaller.

5.4 Cartridge-Actuated Tools. The requirements of 5.4.1 through 5.4.3 shall be applied retroactively.

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

5.4.2 The use of cartridge-actuated tools shall be in accordance with 5.5.2.

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

5.5 Open Flames and Sparks. The requirements of 5.5.1 through 5.5.3 shall be applied retroactively.

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

5.5.2 Grinding, chipping, and other operations that produce either sparks or open flame ignition sources shall be controlled by a hot work permit system in accordance with NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work.*

5.5.3 Smoking shall be permitted only in designated areas.

5.6 Process and Comfort Heating Systems.

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

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

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

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

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

(a) Only fresh makeup air is heated.

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

(c) The exhaust flow is balanced with fresh air intake.

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

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

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

5.8 Industrial Trucks. In areas containing a combustible dust hazard, only industrial trucks listed or approved for the electrical classification of the area, as determined by Section 2.7, shall be used in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation.*

Chapter 6 Fire Protection

6.1 General. Fire 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.

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

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

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

Exception No. 1: Where spark detection and extinguishing systems are provided, the process shall be permitted to continue operating.

Exception No. 2: Where a spark detection system actuates a diverter valve that sends potentially burning material to a safe location.

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

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

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

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

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

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

6.2 Fire Extinguishers.

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

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

6.3 Hose, Standpipes, and Hydrants.

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

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

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

6.4* Automatic Sprinklers.

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

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

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

6.5 Spark/Ember Detection and Extinguishing Systems. Spark/ember detection systems shall be designed, installed, and maintained in accordance with NFPA 69, *Standard on Explosion Prevention Systems*; NFPA 72, *National Fire Alarm Code*; and NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*.

6.6 Special Fire Protection Systems. Automatic extinguishing systems or special hazard extinguishing systems, where provided, shall be designed, installed, and maintained in accordance with the following standards as applicable. The extinguishing systems shall be designed and used in a manner that minimizes the generation of dust clouds during their discharge.

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

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

Chapter 7 Training and Procedures

7.1 Employee Training. The requirements of 7.1.1 through 7.1.3 shall be applied retroactively.

7.1.1 Operating and maintenance procedures and emergency plans shall be developed. The plans and procedures shall be reviewed annually and as required by process changes.

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

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

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

Chapter 8 Inspection and Maintenance

8.1 General Requirements. The requirements of 8.1.1 through 8.1.3 shall be applied retroactively.

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

8.1.2 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

8.1.3 Records shall be kept of maintenance and repairs performed.

8.2 Specific Requirements.

8.2.1 Maintenance of Material-Feeding Devices.

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

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

8.2.2 Maintenance of Air-Moving Devices.

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

8.2.2.2 Maintenance shall not be performed on fans or blowers while the unit is operating.

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

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

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

8.2.3 Maintenance of Air–Material Separators.

8.2.3.1 Air-separation devices that are equipped with a means to dislodge particulate from the surface of filter media shall be inspected periodically as recommended in the manufacturers' instructions for signs of wear, friction, or clogging. These devices shall be adjusted and lubricated accordingly as recommended in the manufacturers' instructions.

8.2.3.2 Air–material separators that recycle air (i.e., cyclones and filter media dust collectors) shall be maintained to comply with 2.1.3.

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

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

8.2.5 Maintenance of Fire and Explosion Protection Systems.

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

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

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

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

Chapter 9 Referenced Publications

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

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

NFPA 10, *Standard for Portable Fire Extinguishers*, 1998 edition.

NFPA 11, *Standard for Low-Expansion Foam*, 1998 edition.

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, 1999 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 2000 edition.

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

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1999 edition.

NFPA 14, *Standard for the Installation of Standpipe, Private Hydrant, and Hose Systems*, 2000 edition.

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

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 1999 edition.

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

NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*, 1998 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 1999 edition.

NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Products Facilities*, 1999 edition.

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

NFPA 70, *National Electrical Code*®, 1999 edition.

NFPA 72, *National Fire Alarm Code*®, 1999 edition.

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

NFPA 86, *Standard for Ovens and Furnaces*, 1999 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, 1999 edition.

NFPA *101*®, *Life Safety Code*®, 2000 edition.

NFPA 120, *Standard for Coal Preparation Plants*, 1999 edition.

NFPA 220, *Standard on Types of Building Construction*, 1999 edition.

NFPA 221, *Standard for Fire Walls and Fire Barrier Walls*, 2000 edition.

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

NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*, 1998 edition.

NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium*, 2000 edition.

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

NFPA 485, *Standard for the Storage, Handling, Processing, and Use of Lithium Metal*, 1999 edition.

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

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 1998 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation*, 1999 edition.

NFPA 651, *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders*, 1998 edition.

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

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*, 1998 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 2000 edition.

NFPA 1124, *Code for the Manufacture, Transportation, and Storage of Fireworks and Pyrotechnic Articles*, 1998 edition.

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

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2000 edition.

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

9.1.2 Other Publications.

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

ASME B 31.3, *Process Piping*, 1999.

ASME *Boiler and Pressure Vessel Code*, Section VIII, 1998.

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

ASTM E 1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, 1998.

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

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

Appendix A Explanatory Material

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

A.1.1.1 Examples of industries that handle combustible particulate solids, either as a process material or as a fugitive or nuisance dust, include but are not limited to the following:

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

A.1.5.2 Air–Material Separator (AMS). Examples include cyclones, bag filter houses, and electrostatic precipitators.

A.1.5.3 Air-Moving Device (AMD). An air-moving device (AMD) is a fan, centrifugal fan, or mixed flow fan. These devices have previously been called blowers or exhausters.

A.1.5.4 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.1.5.5 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.1.5.6 Combustible Dust. Any time a combustible dust is processed or handled, a potential for deflagration exists. The degree of deflagration hazard varies, depending on the type of combustible dust and processing methods used.

A dust explosion has the following four requirements:

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

Evaluation of the hazard of a combustible dust should be determined by the means of actual test data. Each situation should be evaluated and applicable tests selected. The following list represents the factors that are sometimes used in determining the deflagration hazard of a dust:

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

A.1.5.7 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 might be small enough to be classified as dusts. Consequently, the presence of dusts should be anticipated in the process stream, regardless of the starting particle size of the material.

A.1.5.17 Hybrid Mixture. The presence of flammable gases and vapors, even at concentrations less than the lower flammable limit (LFL) of the flammable gases and vapors, will add to the violence of a dust–air combustion.

The resulting dust–vapor mixture is called a *hybrid mixture* and is discussed in NFPA 68, *Guide for Venting of Deflagrations*. In certain circumstances, hybrid mixtures can be deflagrable, even if the dust is below the 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 for hybrid mixtures are mixtures of methane, coal dust, and air or mixtures of gasoline vapor and gasoline droplets in air.

A.1.5.19 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.1.5.20 Lower Flammable Limit (LFL). LFL is also known as minimum explosible concentration (MEC).

A.1.5.21 Minimum Explosible Concentration (MEC). MEC is equivalent to the term *lower flammable limit* for flammable gases. Because it has been customary to limit the use of the term *lower flammable limit* to flammable vapors and gases, an alternative term is necessary for combustible dusts.

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

A.1.5.22 Noncombustible Material. Materials that are reported as having passed ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, should be considered noncombustible materials. For the purposes of this standard, noncombustible construction and limited-combustible construction are both considered to be noncombustible.

A.1.5.23 Pneumatic Conveying System. Pneumatic conveying systems include dust collection systems.

A.1.5.23.1 Negative-Pressure Pneumatic Conveying System. These systems consist of a sequence of an air intake, a material feeder, an air–material separator, an air-moving device, and interconnecting ducts.

A.1.5.23.2 Positive-Pressure Pneumatic Conveying System. Such systems consist of a sequence of an air-moving device, a feeder for introducing materials into the system, an air–material separator, and interconnecting ducts.

A.1.5.33 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.1.5.34 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.1.5.35 Water-Reactive. Water-reactive materials represent a very special fire protection problem. The application of water from fixed water-based extinguishing systems or by the fire service without awareness of the presence of these materials might seriously exacerbate the threat to human life or property. For example, many chemicals form strong acids or bases when mixed with water, 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.2.1.1 The design of the pneumatic conveying system should be coordinated with the architectural and structural designs. The plans and specifications should include a list of all equipment, specifying the manufacturer and type number, and information as shown in (1) through (8). Plans should be drawn to an indicated scale and show all essential details as to location, construction, ventilation ductwork, volume of outside air at standard temperature and pressure that is introduced for safety ventilation, and control wiring diagrams.

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

A.2.1.6 The design basis generally includes, but is not limited to, the general scope of work, design criteria, process description, material flow diagrams, basis for deflagration protection, basis for fire protection systems, and the physical and chemical properties of the process materials.

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

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

A.2.2.3.1 A relatively small initial dust deflagration can disturb and suspend in air dust that has been allowed to accumulate on the flat surfaces of a building or equipment. This dust cloud provides fuel for the secondary deflagration, which can cause damage. Reducing significant additional dust accumulations is therefore a major factor in reducing the hazard in areas where a dust hazard can exist.

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

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

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

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

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

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

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

(d) The 5 percent factor should not be used if the floor area exceeds 20,000 ft^2 (1860 m^2). In such cases, a 1000-ft^2 (93-m^2) layer of dust is the upper limit.

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

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

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

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

A.2.3.2 Window ledges, girders, beams, and other horizontal projections or surfaces can have the tops sharply sloped, or other provisions can be made to minimize the deposit of dust thereon. Overhead steel I-beams or similar structural shapes can be boxed with concrete or other noncombustible material to eliminate surfaces for dust accumulation. Surfaces should be as smooth as possible to minimize dust accumulations and to facilitate cleaning.

A.2.3.9 The use of load-bearing walls should be avoided to prevent structural collapse should an explosion occur.

A.2.4 The design of deflagration venting should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations.*

A.2.4.1 The need for building deflagration venting is a function of equipment design, particle size, deflagration characteristics of the dust, and housekeeping requirements. As a rule, deflagration venting is recommended unless there can be reasonable assurance that hazardous quantities of combustible and dispersible dusts will not be permitted to accumulate outside of equipment.

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

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

A.2.4.2 For further information on restraining vent closures and fireball impingement areas, see NFPA 68, *Guide for Venting of Deflagrations.*

A.2.5 High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust.

A.2.7.2 Refer to NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

A.3.1 The following items describe areas of concern during the design and installation of process equipment:

(1) The elimination of friction by use of detectors for slipping belts, temperature supervision of moving or impacted surfaces, and so forth
(2) Pressure resistance or maximum pressure containment capability and pressure-relieving capabilities of the machinery or process equipment and of the building or room
(3) The proper classification of electrical equipment for the area and condition
(4) Proper alignment and mounting to minimize or eliminate vibration and overheated bearings
(5) The use of electrically conductive belting, low-speed belts, and short center drives as a means of reducing static electricity accumulation *(See Section 5.3.)*
(6) Power transmitted by belt, chain, or shaft
    a. For power transmitted to apparatus within the processing room by belt or chain, a nearly dusttight enclosure of the belt or chain is constructed of substantial noncombustible material that should be maintained under positive air pressure.
    b. For power transmitted by means of shafts, the shafts pass through close-fitting shaft holes in walls or partitions.

A.3.1 Exception. A means to determine protection requirements should be based on a risk evaluation, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. See the American Institute of Chemical Engineers — Center for Chemical Process Safety, *Guidelines for Hazard Evaluation Procedures.*

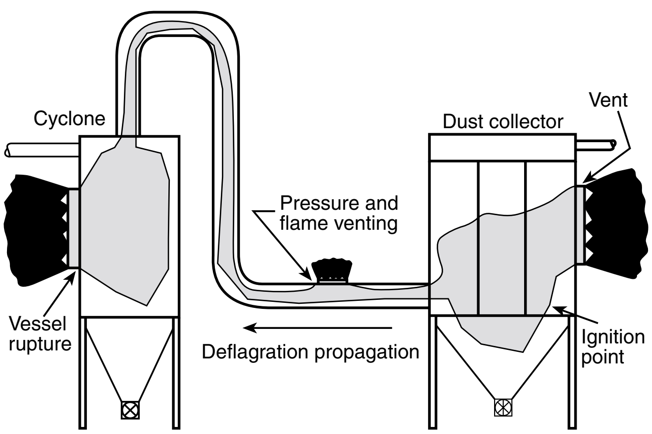
A.3.1.1(1)b The maximum allowable concentration of oxygen is very dependent on the material, its chemical composition, and, in the case of particulate solids, the particle sizes. In addition, with many combustible metals, it is not advisable to completely eliminate oxygen from the transport gas. During transport, particles can be abraded and broken, exposing unoxidized metal (virgin metal) to the transport gas. When this metal is finally exposed to oxygen containing air, the rapid oxidation of this virgin metal could produce sufficient heat to ignite the material. It is, therefore, preferable to provide for a low concentration of oxygen in the transport gas stream to ensure the oxidation of virgin metal as it is exposed during the course of transport.

A.3.1.1(2) Where deflagration venting is used, its design should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations.* For deflagration relief venting through ducts, consideration should be given to the reduction in deflagration venting efficiency caused by the ducts. The relief duct should be restricted to no more than 20 ft (6 m).

A.3.1.1(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.3.1.3 Methods of explosion protection using containment, venting, and suppression protect the specific process equipment on which they are installed. Flame fronts from a deflagration can propagate through connecting ductwork to other unprotected process equipment and to the building from outside process equipment. Figure A.3.1.3 shows an example of how this propagation might occur. Isolation techniques as shown in Figures A.3.1.3.1(3) through (5) can be used to prevent the propagation of the deflagration by arresting the flame front.

FIGURE A.3.1.3 An example of deflagration propagation without isolation.



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

The dynamics of a dust explosion are such that unburned dust is pushed ahead of the flame front by the expanding products of combustion. This dust is expelled from the containment vessel via every available exit path, in all possible directions of flow, including flow via all connecting ducts and out through any provided explosion venting. The driving force pushing the dust away from the point of initiation (which, under vented conditions, might be in the range of a few psi) can easily overcome the force of normal system flow (which typically might be of the order of a few inches water column). Furthermore, the velocities produced by the deflagration usually greatly exceed those of the pneumatic conveying system under normal design conditions. Consequently, unburned dust and the deflagration flame front can be expected to propagate upstream through ductwork from the locus of the initial deflagration.

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

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

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

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

A.3.1.3.1(1) Figure A.3.1.3.1(1) illustrates two different designs of chokes.

A.3.1.3.1(2) When rotary valves are installed in both the inlet and outlet of equipment, care should be taken to ensure that the rotary valve on the inlet is stopped before the unit becomes overfilled. See Figure A.3.1.3.1(2).

A.3.1.3.1(3) Figure A.3.1.3.1(3) illustrates one example of deflagration propagation using mechanical isolation.

A.3.1.3.1(4) Figure A.3.1.3.1(4) illustrates one example of deflagration propagation using flame front diversion.

A.3.1.3.1(5) Figure A.3.1.3.1(5) illustrates one example of deflagration propagation using chemical isolation.

FIGURE A.3.1.3.1(1) Two examples of screw conveyor chokes.

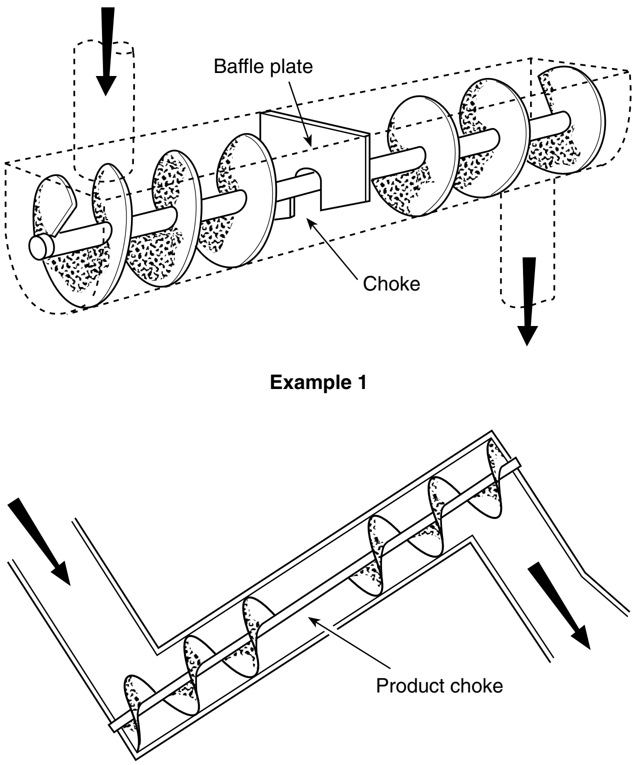


FIGURE A.3.1.3.1(2) An example of rotary valves.

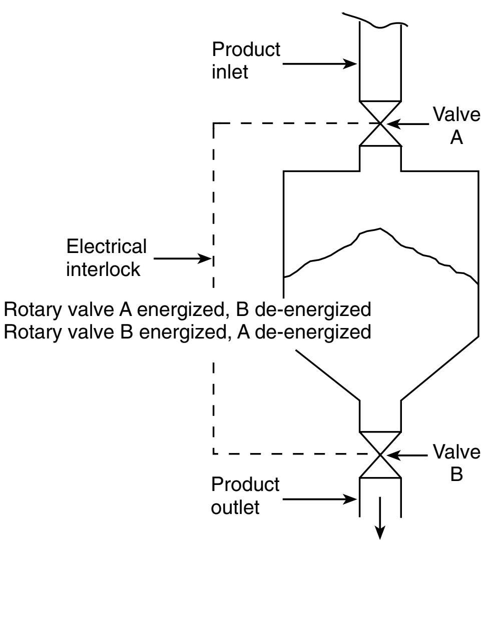


FIGURE A.3.1.3.1(3) An example of deflagration propagation using mechanical isolation.

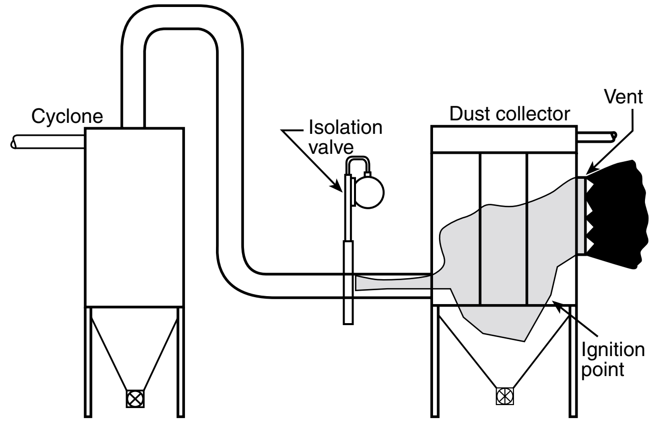


FIGURE A.3.1.3.1(4) An example of deflagration propagation using flame front diversion.

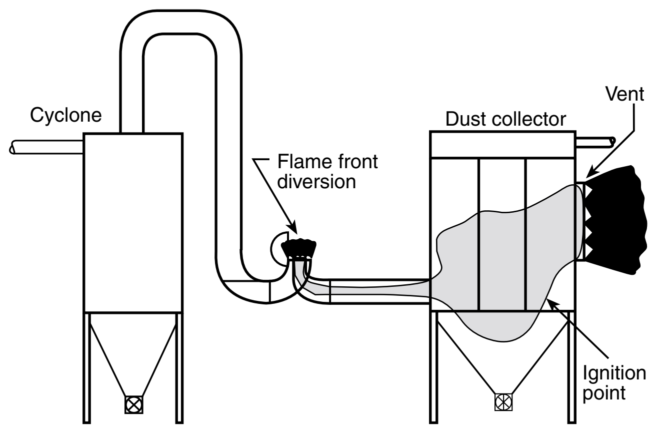
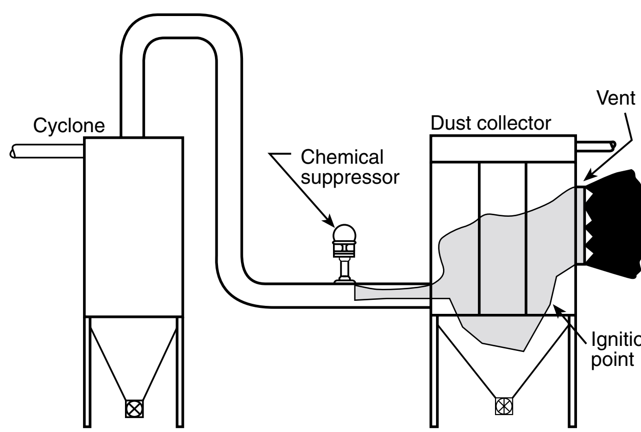


FIGURE A.3.1.3.1(5) An example of deflagration propagation using chemical isolation.



A.3.1.3.1 Exception No. 2. See A.3.1 Exception text for an explanation of the considerations in a documented risk evaluation.

A.3.1.3.2 Exposures of concern include, but are not limited to, bagging operations and hand-dumping operations where the discharge of a fireball from the pickup point would endanger personnel.

A.3.2.1 Exception. Shipping containers can pose a deflagration hazard; however, deflagration protection measures for these units are not always practical. Consideration should be given to deflagration hazards when electing to omit deflagration protection.

A.3.2.3.2 Exception No. 2. Where explosion venting is used, its design should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations*. For explosion relief venting through ducts, consideration should be given to the reduction in explosion venting efficiency caused by the ducts. The ducts should be designed with a cross-sectional area at least as large as the vent. They should be structurally as strong as the air–material separator and should be limited in length to 20 ft (6 m). Since any bends will cause increases in the pressure developed during venting, vent ducts should be as straight as possible. If bends are unavoidable, they should be as shallow angled (i.e., have as long a radius) as is practicable.

A.3.2.3.2 Exception No. 3. Small containers can pose an explosion hazard; however, explosion protection measures for these units are not always practicable. Consideration should be given to explosion hazards when electing to omit protection.

A.3.2.3.3 Exception No. 2. See A.3.2.3.2 Exception No. 3.

A.3.2.4 Horizontal projections can have the tops sharply sloped to minimize the deposit of dust thereon. Efforts should be made to minimize the amount of surfaces where dust can accumulate.

A.3.2.5 For information on designing deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A.3.3.3.2 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.3.4.1.1 Whether a metallic particulate reacts with water depends on particle size, chemical purity of the particulate, oxygen concentration, and combustion temperature. Consequently, an engineering analysis should be performed prior to selecting an extinguishment strategy. In some cases, a rapidly discharged high-volume water spray system has been shown to be effective due to the rapid absorption of heat.

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

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

A.3.6.3 Whenever a duct size changes, the cross-sectional area changes as well. This change in area causes a change in air velocity in the region of the change, introducing turbulence effects. The net result is that a transition with an included angle of more than 30 degrees represents a choke when the direction of flow is from large to small and results in localized heating and static electric charge accumulation. When the transition is from small to large, the air velocity drop at the transition is usually enough to cause product accumulation at the transition and the existence of a volume where the concentration of combustible is above the MEC. It is strongly desirable to avoid both of these situations.

A.3.6.4 Isolation devices in accordance with 3.1.3 are provided to prevent deflagration propagation between connected equipment. According to 3.1.3, 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.3.8.2 For information on deflagration pressure relief, see A.3.1.1(2).

A.3.10 It is recommended that bucket elevators be located outside of buildings wherever practicable. Although explosion protection for bucket elevators is required in 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.3.10.1 Deflagration vents on bucket elevators should be distributed along the casing side in pairs, opposite each other, next to the ends of the buckets. Each deflagration vent should be a minimum of two-thirds of the cross-sectional area of the leg casing and should be located approximately 20 ft (6 m) apart. Vent closures should be designed to open at an internal gauge pressure of 0.5 psi to 1.0 psi (3.4 kPa to 6.9 kPa). Vent closure devices should be secured to eliminate the possibility of the closures becoming missiles. Vent materials should be of lightweight construction and meet the guidelines given in NFPA 68, *Guide for Venting of Deflagrations*.

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

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

For bucket elevators inside of buildings, vent ducts should be designed with a cross-sectional area at least as large as the vent, should be structurally as strong as the bucket elevator casing, and should be limited in length to 10 ft (3 m). Since any bends will cause increases in the pressure developed during venting, vent ducts should be as straight as possible. If bends are unavoidable, they should be as shallow-angled (i.e., have as long a radius) as practicable.

A.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.3.10.8 The motor selected should not be larger than the smallest standard motor capable of meeting this requirement.

A.3.11 Explosion protection should be provided when the risk is significant. *(See 3.1.1.)*

A.3.12.2 Exception No. 1. Some systems are designed to operate at solids concentrations that pose no fire or deflagration risk. Such systems include nuisance dust exhaust systems and the downstream side of the last air–material separator in the pneumatic conveying system.

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

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

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

A.3.12.2 Exception No. 2. 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.3.13.1.1 Exception No. 2. Where deflagration venting is used, its design should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations*. For deflagration relief venting through ducts, consideration should be given to the reduction in deflagration venting efficiency caused by the ducts. The ducts should be designed with a cross-sectional area at least as large as the vent, should be structurally as strong as the dust collector, and should be limited in length to 20 ft (6 m). Because any bends will cause increases in the pressure that develops during venting, vent ducts should be as straight as possible. If bends are unavoidable, they should be as shallow-angled (i.e., have as long a radius) as practicable.

A.3.13.1.5 For design requirements for fast-acting dampers and valves, flame front diverters, and flame front extinguishing systems, see NFPA 69, *Standard on Explosion Prevention Systems*.

A.3.13.2.3.5 See NFPA 68, *Guide for Venting of Deflagrations*.

A.3.15 Size reduction machinery includes equipment such as mills, grinders, and pulverizers.

A.3.16 Particle separation devices include screens, sieves, aspirators, pneumatic separators, sifters, and similar devices.

A.3.16.3 For information on designing deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A.3.16.3 Exception. 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.3.18 Dryers include tray, drum, rotary, fluidized bed, pneumatic, spray, ring, and vacuum types. Dryers and their operating controls should be designed, constructed, installed, and monitored so that required conditions of safety for operation of the air heater, the dryer, and the ventilation equipment are maintained.

A.3.18.8 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 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 the U.S. Bureau of Mines, Report of Investigations, RI 8798, "Thermal and Electrical Ignitability of Dusts," Conti, R. S. et al. (modified Godbert-Greenwald furnace, the BAM Furnace, or other methods). The dust layer ignition temperature can be determined by the Bureau of Mines test procedure in Lazzara and Miron, "Hot Surface Ignition Temperatures of Dust Layers."

A.4.2.1 See A.2.2.3.1.

A.4.2.2 Vacuum cleaning systems are the preferred method for cleaning surfaces.

A.5.1.1.3 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 3.1.1 are appropriate. Conversely, if the analysis indicates that the particle size and concentration do not predict a propagating flame front through the fuel–air mixture, the fire protection methods in Chapter 6 should be considered.

A.5.1.1.4 Particular attention should be paid to combustible particulate solids where they are introduced into the process stream. Some sources of particulate might 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 must be carefully evaluated.

See Figures A.5.1.1.4(a) and (b) for examples of foreign material removal.

A.5.1.2 Transmission of power by direct drive should be used, where possible, in preference to belt or chain drives.

A.5.1.3 Consideration should be given to the potential for overheating caused by dust entry into bearings. Bearings should be located outside the combustible dust stream, where they are less exposed to dust and more accessible for inspection and service. Where bearings are in contact with the particulate solids stream, sealed or purged bearings are preferred.

FIGURE A.5.1.1.4(a) An example of a pneumatic separator.

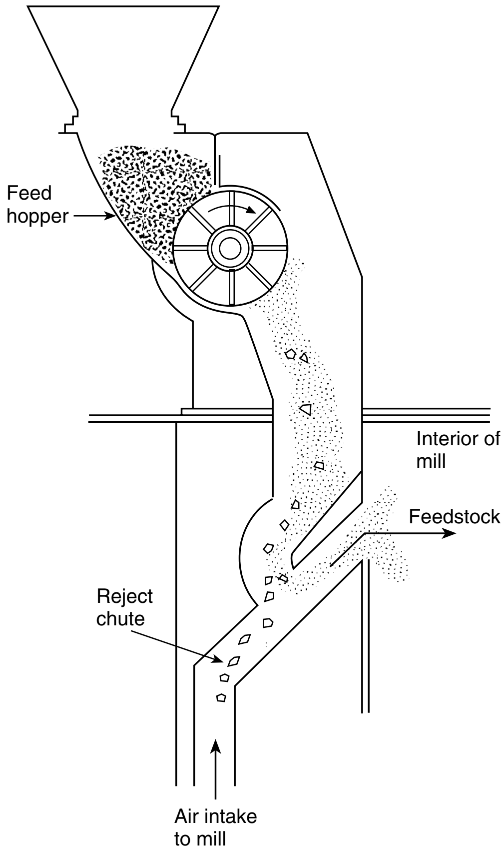
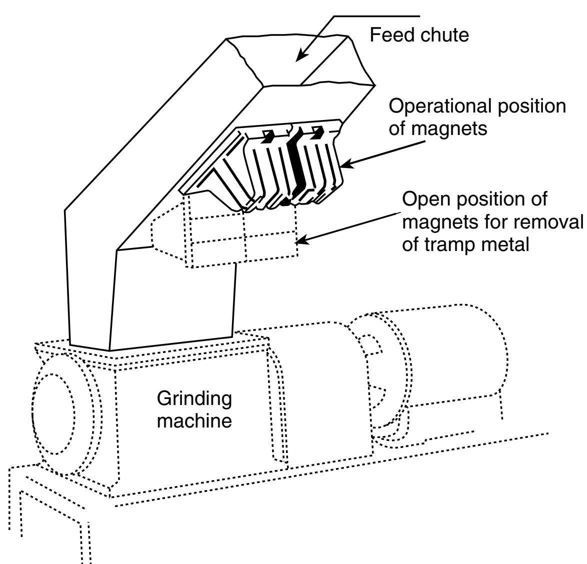


FIGURE A.5.1.1.4(b) An example of a magnetic separator.



A.5.3 See NFPA 77, *Recommended Practice on Static Electricity*, for information on this subject.

A.5.3.1 Bonding minimizes the potential difference between conductive objects. Grounding minimizes the potential difference between objects and ground.

A.5.3.3 Exception. Certain fabrics that pose significantly less risk of ignition in flammable atmospheres have been developed for use in FIBCs. One such fabric that has been tested for use in atmospheres having a minimum ignition energy of 0.25 mJ or greater and has been used in FIBCs is documented in Ebadat and Mulligan, "Testing the Suitability of FIBCs for Use in Flammable Atmospheres."

A.5.6.1 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.5.7 The ignition temperature of a layer of dust on hot surfaces might decrease over time if the dust dehydrates or carbonizes. For this reason, the hot surfaces should not exceed the lower of either the ignition temperature (in °C) or 165°C (329°F). The ignition temperatures for many materials are shown in NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

A.6.1.1 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.

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

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

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

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

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

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

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

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

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

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

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

Often an inerted system is used because of the difficulties encountered in extinguishing these materials. However, it should be noted that some commonly considered inerting agents, such as CO_2 or nitrogen, might be incompatible with certain metals at high temperatures.

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

A.6.2.2 Extreme care must be employed when using hand-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, is virtually certain.

Consequently, when hand-portable fire extinguishers are used in areas that contain accumulated combustible dusts (*refer to A.2.2.3.1*), the extinguishing agent should be applied in a manner that does not disturb or disperse accumulated dust. Generally, fire extinguishers are designed to maximize the delivery rate of the extinguishing agent to the fire. Special techniques of fire extinguisher use must be employed to prevent this inherent design characteristic of the fire extinguisher from producing an unintended deflagration hazard.

A.6.4 Automatic sprinkler protection within dust collectors, silos, and bucket elevators should be considered. Considerations should include the combustibility of the equipment, the combustibility of the material, and the amount of material present.

A.6.4.1 A risk evaluation should consider the presence of combustibles both in the equipment and 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 within dust collectors, silos, and bucket elevators should be considered.

A.7.1.3(7) All plant personnel, including management, supervisors, and maintenance and operating personnel, should be trained to participate in plans for controlling plant emergencies. Trained plant fire squads or fire brigades should be maintained.

The emergency plan should contain the following elements:

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

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

A.8.1.2(5) Process interlocks should be calibrated and tested in the manner in which they are intended to operate, with written test records maintained for review by management. Testing frequency should be determined in accordance with the AIChE *Guidelines for Safe Automation of Chemical Processes*.

A.8.2.2.4 Periodic cleaning of components is especially important if the blower or fan is exposed to heated air.

A.8.2.2.5 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.8.2.5.3 For information on maintenance of deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations.*

Appendix B Additional Information on Explosion Protection

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

B.1 General. This section 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 within the vessel prior to the deflagration. NFPA 69, *Standard on Explosion Prevention Systems*, limits this 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 following is the major advantage of containment: low maintenance — passive.

The following are disadvantages of containment:

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

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

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

The following is the major advantage of inerting: Prevention of combustion, thereby avoiding product loss.

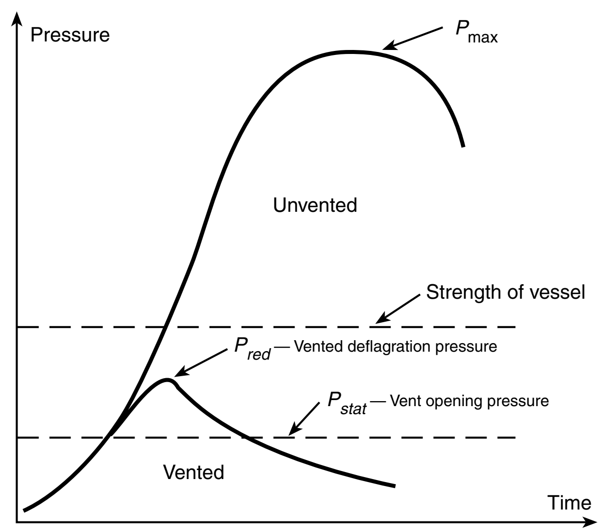
The following are disadvantages of inerting:

(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 within a process component or room.

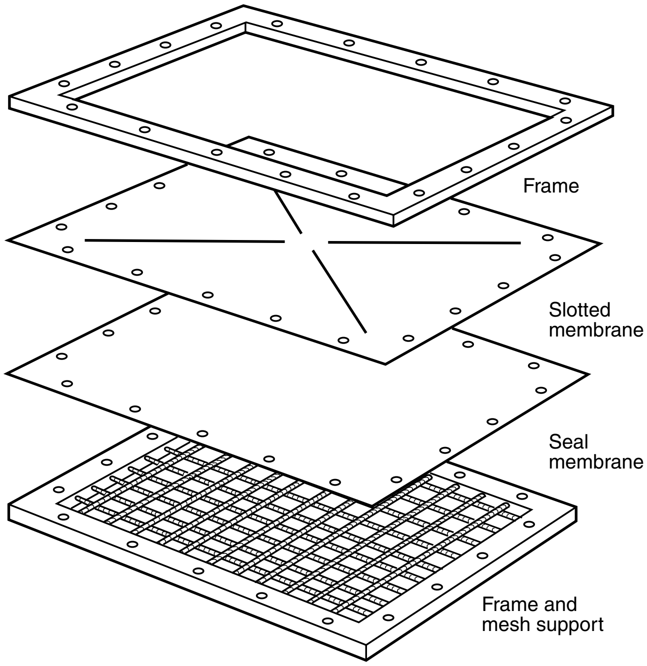
B.4.1 How Deflagration Venting Works. Except for an open vent, which allows flammable gases to discharge directly to the atmosphere, deflagration vents open at a predetermined pressure referred to as P_{stat}. The vent is either a vent panel or a vent door. The pressurized gases are discharged to the 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.

FIGURE B.4.1 Pressure–time graph of a vented deflagration.



B.4.2 Deflagration Vent Panel. The deflagration vent panel is a flat or slightly domed panel that is bolted or otherwise attached to an opening on the process component to be protected. The panel can be made of any material and construction that will allow the panel to either rupture, detach, or swing open from the protected volume; materials that could fragment and act as shrapnel should not be used. Flat vents 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. These vents are either rectangular or circular.

FIGURE B.4.2 Deflagration vent panel and support grid.



B.4.3 Deflagration Vent Door. A deflagration vent door is a hinged door mounted on the process component to be protected. It is designed to open at a predetermined pressure that is governed by a special latch arrangement. Generally, a vent door has a greater inertia than a vent panel, reducing its efficiency.

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

The following are advantages of deflagration venting:

(1) Low cost, if the process component is located outside
(2) Low maintenance — passive device

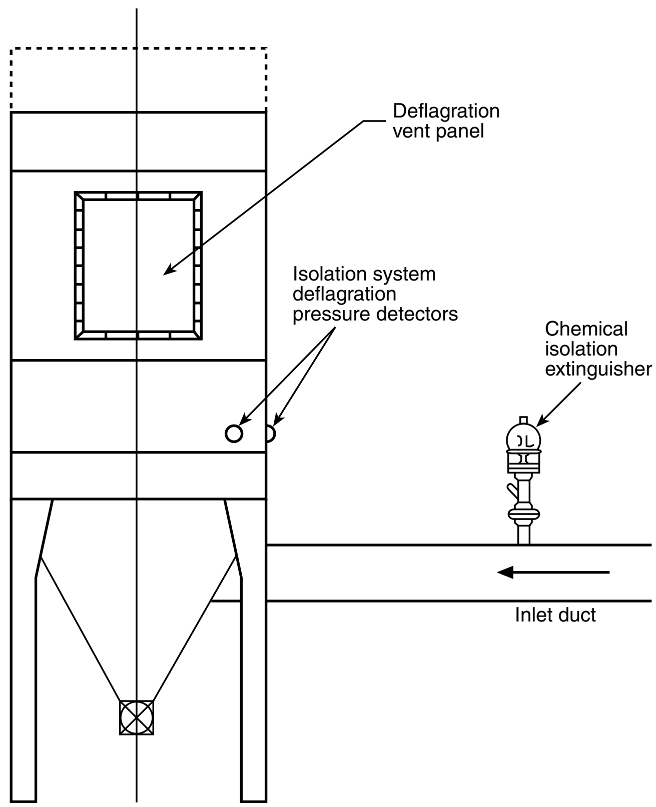
The following are disadvantages of deflagration venting:

(1) The potential for a postventing fire within the component, particularly if combustible materials, such as filter bags, are still present
(2) The recommendation that the plant component be near an outside wall or located outside
(3) Fireball exiting a vented component, which is a severe fire hazard to the plant and personnel located in the vicinity of the deflagration vent opening
(4) Contraindication of the process for toxic or corrosive material

B.4.5 Design Considerations. The following points should be considered when designing and evaluating 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 back pressure
(8) Thermal insulation
(9) Safe venting area
(10) Vacuum protection
(11) Location

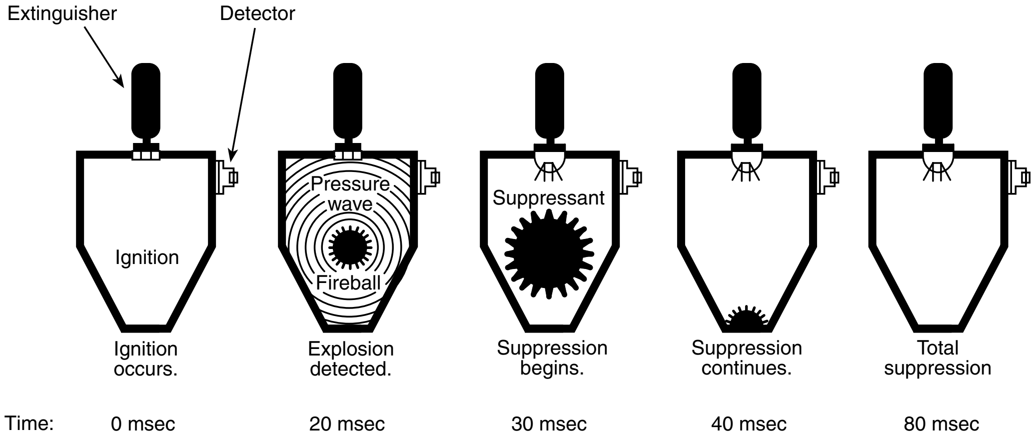
FIGURE B.4.4 An example of a vented dust collector.



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

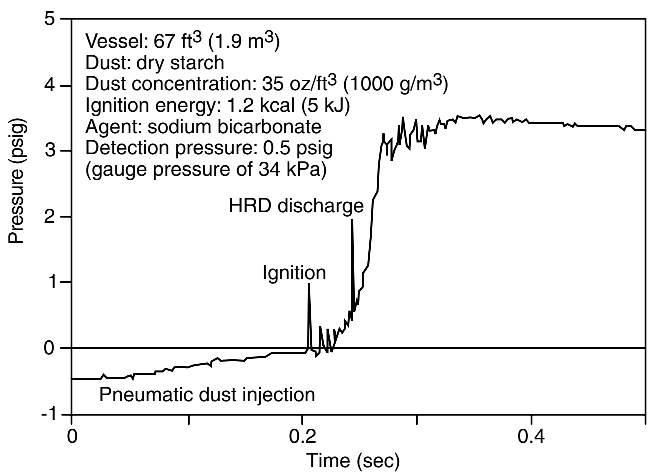
B.5.1 How Deflagration Suppression Works. An explosion is not an instantaneous event. The growing fireball has a measurable time to create its destructive pressures. Typically the fireball expands at speeds of 30 ft/sec (9 m/sec), whereas the pressure wave ahead of it travels at 1100 ft/sec (335 m/sec).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

FIGURE B.5.1(a) Deflagration suppression sequence — starch in 35-ft^3 (1-m^3) vessel.



In suppressing the fireball at its 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 65-ft^3 (1.9-m^3) vessel. Note that the reduced deflagration gauge pressure is approximately 3.5 psi (24 kPa) in this test.

FIGURE B.5.1(b) Suppressed deflagration: pressure *vs.* time.



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

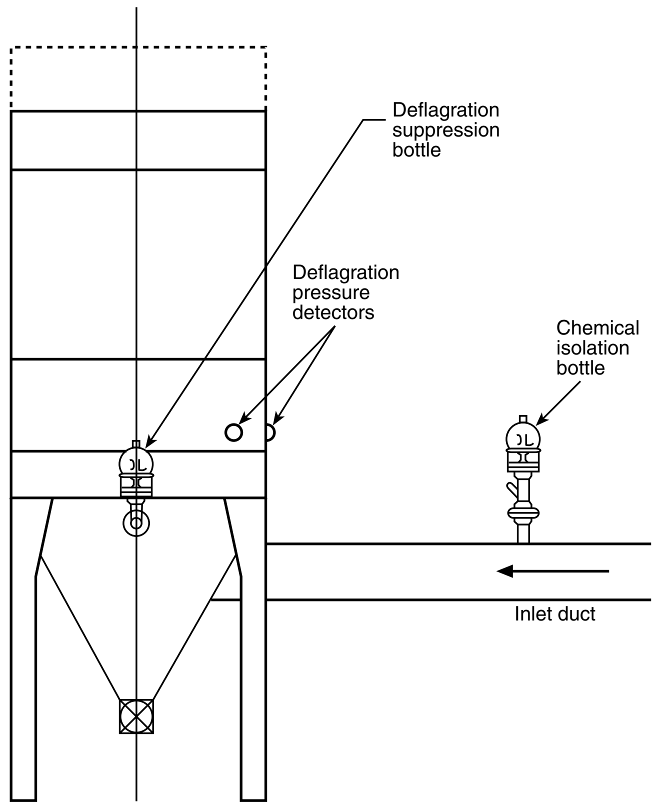
The following are advantages of a deflagration suppression system:

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

The following are disadvantages of a deflagration suppression system:

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

FIGURE B.5.2 An example of a dust collector suppression system.



B.5.3 Design Criteria. Deflagration suppression systems are designed in accordance with NFPA 69, *Standard on Explosion Prevention Systems*; and ISO 6184-4, *Explosion Protection Systems — Part 4: Determination of Efficiency of Explosion Suppression Systems*. The following information is required to design 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 might 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 might save it from destruction. However, the inlet duct might still propagate flame to other parts of the plant. Such propagation can and has resulted in devastating secondary explosions. The importance of ducts is stated in NFPA 68, *Guide for Venting of Deflagrations*, which says:

> Interconnections between separate pieces of equipment present a special hazard. . . . Where such interconnections are necessary, deflagration isolation devices should be considered, or the interconnections should be vented (**68:**3-67).

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

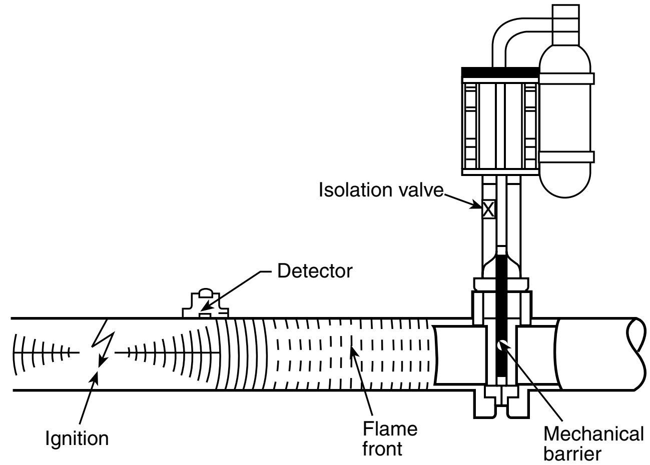
The need for isolation is further supported by research that shows that interconnecting vessels can result in precompression of gases within connected vessels caused by a deflagration. The result is that a deflagration in one vessel can produce considerably higher pressures in the connected vessel. Mechanical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

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

Rotary airlock valves for deflagration isolation should be of rugged construction and suitable design. Such design is particularly important for pieces of equipment protected by deflagration venting and containment. This requirement puts more demand on the integrity of rotary airlock valves than for 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 might be a pressure switch or an optical detector, detects the deflagration pressure or flame front. This 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.

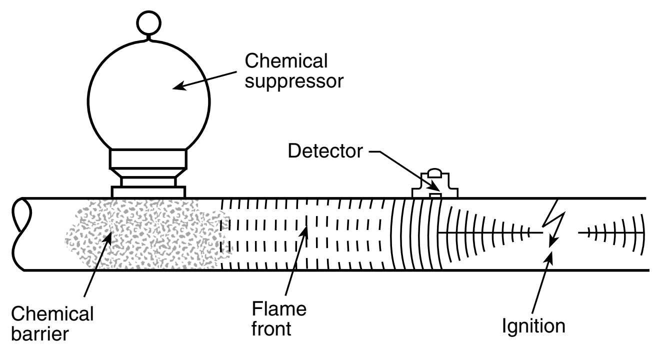
FIGURE B.6.1 An example of mechanical isolation.



B.6.2 Chemical Isolation. Chemical isolation is achieved by the rapid discharge of a chemical extinguishing agent in the interconnecting pipe or duct. Figure B.6.2 shows a typical arrangement for chemical isolation. A deflagration detector, which might be a pressure switch or an optical detector, detects the deflagration pressure or flame front. This 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.6.2 An example of chemical isolation.



B.7 Limitations of Flame Front Diverters. Flame front diverters can divert deflagration flames by directing them to the atmosphere. However, these devices do have limitations. If the air-moving device is located downstream of the flame front 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 might be ineffective in completely diverting a deflagration involving a hybrid mixture whose vapors exceed the LFL, regardless of the location of the air-moving device. In both of these situations where a flame front diverter will allow