



First Revision No. 30-NFPA 652-2016 [Global Input]

All instances of Dust Hazard Analysis should be Dust Hazards Analysis. Please change to the plural all throughout

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 15:07:09 EDT 2016

Committee Statement

Committee Statement: Establishes consistent terminology throughout the document.

Response Message:



First Revision No. 45-NFPA 652-2016 [Global Input]

Change title of Section 8.3.4 from AMS Locations to AMS. (delete the term location)

Current section 8.3.5 (AMS Clean Exhaust) should be renumbered 8.3.4.3 - renumber all subsequent sections.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 15 10:58:03 EDT 2016

Committee Statement

Committee Statement: Clarifies title of section and revises numbering of the chapter to reflect the committees intent.

Response Message:

**First Revision No. 52-NFPA 652-2016 [Global Input]**

Move 8.4, Housekeeping, 8.6, PPE, and 8.5.3, Hot Work to Chapter 9, right after 9.3. Leave heading for 8.5.3, Hot Work, in Chapter 8 and refer the reader to the new location in Chapter 9 for the requirements.

Supplemental Information

<u>File Name</u>	<u>Description</u>
652-2016_Chapter_8_Material_to_be_moved..docx	

Submitter Information Verification

Submitter Full Name: Susan Bershad
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 16 11:17:56 EDT 2016

Committee Statement

Committee Statement: The committee is moving several of the management system elements from Chapter 8 to Chapter 9. Management system requirements are more appropriately located in Chapter 9, which is titled, Management Systems. This makes it clear to the user that they are retroactive, and that they are retained prescriptive requirements for the performance-based design option. These sections are 8.4, Housekeeping, 8.6, Personnel Protective Equipment, and 8.5.3, Hot Work.

Response Message:

8.4 Housekeeping.

8.4.1 General.

Unless otherwise specified, the requirements of Section 8.4 shall be applied retroactively.

8.4.2* Methodology.

8.4.2.1 Procedure.

8.4.2.1.1*

Housekeeping procedures shall be documented.

8.4.2.1.2*

The methods used for cleaning surfaces shall be selected on the basis of reducing the potential for creating a combustible dust cloud.

8.4.2.1.3

Cleaning methods to be used shall be based on the characteristics of the material and quantity of material present.

8.4.2.2 Vacuum Cleaning Method.



First Revision No. 10-NFPA 652-2016 [Edit](#) [Hide Markup](#)

8.4.2.2.1*

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

- (1) Materials of construction shall comply with 8.5.7.1.
- (2) Hoses shall be conductive or static dissipative.
- (3) All conductive components, including wands and attachments, shall be bonded and grounded.
- (4) ~~Dust-laden air shall not pass through the fan or blower.~~ The fan or blower shall be on the clean-side of the primary filtration media or wet separation chamber.
- (5) ~~Electrical motors shall not be in-located on the dust-laden air stream-dirty-side of the primary filtration media or wet separation chamber unless listed for Class II, Division 1, locations.~~
- (6) * Where liquids or wet materials are picked up by the vacuum cleaner, paper filter elements shall not be used.
- (7) Vacuum cleaners used for metal dusts shall meet the requirements of NFPA 484.

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

- (1) Materials of construction shall comply with 8.5.7.1.
- (2) Hoses shall be conductive or static dissipative.
- (3) All conductive components, including wands and attachments, shall be bonded and grounded.
- (4) Dust-laden air shall not pass through the fan or blower.

- (5) Electrical motors shall not be in the dust-laden air stream unless listed for Class II, Division 1, locations.
- (6) *Where liquids or wet materials are picked up by the vacuum cleaner, paper filter elements shall not be used.
- (7) Vacuum cleaners used for metal dusts shall meet the requirements of NFPA 484.

8.4.2.2.2*

In Class II electrically classified (hazardous) locations, electrically powered vacuum cleaners shall be listed for the purpose and location or shall be a fixed-pipe suction system with a remotely located exhauster and an AMS installed in conformance with Section 8.3, and they shall be suitable for the dust being collected.



First Revision No. 11-NFPA 652-2016

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8.4.2.2.3

~~Where In Class II areas where flammable vapors or gases are present, vacuum cleaners shall be listed for both Class I and Class II hazardous locations.~~

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

8.4.2.3* Sweeping, Shoveling, Scoop, and Brush Cleaning Method.

The use of scoops, brooms, and brushes for sweeping and shoveling shall be a permitted cleaning method.

8.4.2.4* Water Washdown Cleaning Method.

8.4.2.4.1

The use of water washdown shall be a permitted cleaning method.

8.4.2.4.2

Where the combustible dust being removed is metal or metal-containing dust or powder within the scope of NFPA 484 the requirements of NFPA 484 shall be followed.

8.4.2.4.3*

Where the combustible dust being removed is a water-reactive material, additional precautions shall be taken to control the associated hazards.

8.4.2.5 Water Foam Washdown Systems. (Reserved)

8.4.2.6 Compressed Air Blowdown Method.

8.4.2.6.1*

Blowdowns using compressed air shall be permitted to be used as a cleaning method in accordance with the provisions of 8.4.2.6.2.

8.4.2.6.2*

Where blowdown using compressed air is used, the following precautions shall be followed:

- (1) Prior to using compressed air, vacuum cleaning, sweeping, or water washdown methods are used to clean surfaces that can be safely accessed.
- (2) Dust accumulations in the area after vacuum cleaning, sweeping, or water washdown do not exceed the threshold housekeeping dust accumulation.

- (3) Compressed air hoses are equipped with pressure relief nozzles limiting the discharge pressure to 30 psi (207 kPa) in accordance with OSHA requirements in 29 CFR 1910.242(b).
- (4) All electrical equipment, including lighting, potentially exposed to airborne dust in the area during cleaning is suitable for use in a Class II, Division 2, hazardous (classified) location in accordance with *NFPA 70*.
- (5) All ignition sources and hot surfaces capable of igniting a dust cloud or dust layer are shut down or removed from the area.
- (6) After blowdown is complete, residual dust on lower surfaces is cleaned prior to re-introduction of potential ignition sources.
- (7) Where metal or metal-containing dust or powder under the scope of NFPA 484 is present, the requirements of NFPA 484 apply.

8.4.2.7 Steam Blow Down Method. (Reserved)

8.4.3 Training.

Employee and contractor training shall include housekeeping procedures, required personal protective equipment (PPE) during housekeeping, and proper use of equipment.

8.4.4 Equipment. (Reserved)

8.4.5 Vacuum Trucks.

8.4.5.1

Vacuum trucks shall be grounded and bonded.

8.4.5.2

Vacuum truck hoses and couplings shall be static dissipative or conductive and grounded.

8.4.6 Frequency and Goal.

8.4.6.1*

Housekeeping frequency and accumulation goals shall be established to ensure that the accumulated fugitive dust levels on surfaces do not exceed the threshold housekeeping dust accumulation limits.

8.4.6.2

The threshold housekeeping dust accumulation limits shall be in accordance with the industry- or commodity-specific NFPA standard. (See [1.3.1.](#))

8.4.6.3*

Provisions for unscheduled housekeeping shall include specific requirements establishing time to clean local dust spills or transient releases.

8.4.7 Auditing and Documentation.

8.4.7.1*

Housekeeping effectiveness shall be assessed based on the results of routine scheduled cleaning and inspection, not including transient releases.

8.4.7.2

The owner/operator shall retain documentation that routine scheduled cleaning occurs in accordance with the frequency and accumulation goals established in [8.4.6.1.](#)

8.5.3 Hot Work.



8.5.3.1*

All In addition to the requirements of NFPA 51B, all hot work activities shall comply with 8.5.3.2 through 8.5.3.5 the following requirements of NFPA 51B.

All hot work activities shall comply with the requirements of NFPA 51B.

8.5.3.2*

The area affected by hot work shall be thoroughly cleaned of combustible dust prior to commencing any hot work.

8.5.3.3

Equipment that contains combustible dust and is located within the hot work area shall be shut down, shielded, or both.

8.5.3.4

When the hot work poses an ignition risk to the combustible dust within equipment, the equipment shall be shut down and cleaned prior to commencing such hot work.

8.5.3.5

Floor and wall openings within the hot work area shall be covered or sealed.



8.5.3.6 Portable Electrical Equipment. ~~(Reserved)~~

Use of portable electrical equipment that does not comply with the electrical classification of the area where it is to be used shall be authorized and controlled in accordance with the hot work procedure as outlined in this section

8.6 Personal Protective Equipment.

8.6.1 Workplace Hazard Assessment.

8.6.1.1*

An assessment of workplace hazards shall be conducted as described in NFPA 2113.

8.6.1.2

When the assessment in 8.6.1.1 has determined that flame-resistant garments are needed, personnel shall be provided with and wear flame-resistant garments.

8.6.1.3*

When flame-resistant clothing is required for protecting personnel from flash fires, it shall comply with the requirements of NFPA 2112.

8.6.1.4*

Consideration shall be given to the following:

- (1) Thermal protective characteristics of the fabric over a range of thermal exposures
- (2) Physical characteristics of the fabric
- (3) Garment construction and components
- (4) Avoidance of static charge buildup
- (5) Design of garment
- (6) Conditions under which garment will be worn

- (7) Garment fit
- (8) Garment durability/wear life
- (9) Recommended laundering procedures
- (10) Conditions/features affecting wearer comfort

8.6.1.5

Flame-resistant garments shall be selected, procured, inspected, worn, and maintained in accordance with NFPA 2113.

8.6.1.6*

The employer shall implement a policy regarding care, cleaning, and maintenance for flame-resistant garments.

8.6.2 Limitations of PPE Application. (Flame-Resistant Garments)

8.6.2.1*

When required by 8.6.1.2, flame-resistant or non-melting undergarments shall be used.

8.6.2.2*

When determined by 8.6.1.1 that flame-resistant garments are needed, only flame-resistant outerwear shall be worn over flame-resistant daily wear.

8.6.3 Limitations of PPE to Combustible Dust Flash Fires. (Reserved)

8.6.4 Face, Hands, and Footwear Protection. (Reserved)

**First Revision No. 6-NFPA 652-2016 [Section No. 1.3.3]****1.3.3**

This standard shall not apply to the following:

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

Supplemental Information

<u>File Name</u>	<u>Description</u>
Annex_Material_for_FR-2.docx	

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 08 18:14:16 EDT 2016

Committee Statement

Committee Statement: Response to PI-29. Adds annex material to 1.3.3 (4).

Response Message:

Annex Material for FR-2

Warehousing includes the storage of bags, super-sacks, or other containers of combustible dusts where no processing or handling of the dusts is performed, except for moving closed containers or loaded pallets. If the business activity of the facility or specific areas of the facility are confined to strictly warehousing, then the standard does not apply. However, if the facility is processing or handling the dusts outside of the closed containers (e.g. opening containers and dispensing dusts), then the facility is required to meet all of all of the applicable requirements of this standard.

**First Revision No. 2-NFPA 652-2016 [Section No. 1.4.1]****1.4.1***

For the purposes of this standard, the industry- or commodity-specific NFPA standards shall include the following:

- (1) NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*
- (2) NFPA 484, *Standard for Combustible Metals*
- (3) NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*
- (4) NFPA 655, *Standard for Prevention of ~~Sulfure~~ Sulfur Fires and Explosions*
- (5) NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 08 15:20:09 EDT 2016

Committee Statement

Committee Statement: Fixing typographical error.

Response Message:

[Public Input No. 62-NFPA 652-2016 \[Section No. 1.4.1\]](#)

**First Revision No. 3-NFPA 652-2016 [Section No. 2.3.2]****2.3.3** ASTM Publications.

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

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

ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, 2007 2014 .

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submission Date: Mon Aug 08 15:21:58 EDT 2016

Committee Statement

Committee Statement: Date updates.

Response Message:

[Public Input No. 4-NFPA 652-2016 \[Section No. 2.3.2\]](#)

**First Revision No. 67-NFPA 652-2016 [Section No. 2.4]****2.4** References for Extracts in Mandatory Sections.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 2014 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, ~~2013~~ 2018 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2014 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, ~~2015~~ 2018 edition.

NFPA 484, *Standard for Combustible Metals*, 2015 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, ~~2013~~ 2017 edition.

NFPA 921, *Guide for Fire and Explosion Investigations*, ~~2014~~ 2017 edition.

NFPA 1250, *Recommended Practice in Fire and Emergency Services Organization Risk Management*, ~~2015~~ 2018 edition.

NFPA 1451, *Standard for a Fire and Emergency Service Vehicle Operations Training Program*, ~~2013~~ 2018 edition.

NFPA 5000® , *Building Construction and Safety Code*® , 2018 edition.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 18 11:09:58 EDT 2016

Committee Statement

Committee Statement: Change in edition dates for extracts - changes made for first draft only. Additional extracts will be updated at second draft.

Response Message:

**First Revision No. 4-NFPA 652-2016 [New Section after 3.1]**

3.3.19* Explosible.

Capable of propagating a deflagration when dispersed in air or the process-specific oxidizing media.

Supplemental Information

<u>File Name</u>	<u>Description</u>
Annex_Material_for_FR-4.docx	

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submission Date: Mon Aug 08 15:34:31 EDT 2016

Committee Statement

Committee Statement: The term explosible is used in this and other NFPA combustible dust standards and a uniform definition should be developed. The annex refers to NFPA 68.

Response

Message:

Public Input No. 63-NFPA 652-2016 [New Section after 3.1]

Annex Material for FR-4

A 3.3.x For dusts, explosibility is determined as described in Section 5.4.3. For hybrid mixtures, see NFPA 68.

**First Revision No. 36-NFPA 652-2016 [Section No. 3.3.1.1]****3.3.2.1** Enclosureless AMS.

An air-material separator designed to separate the conveying air from the material being conveyed where the filter ~~medium is~~ media are not enclosed or in a container.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 11 08:22:26 EDT 2016

Committee Statement

Committee Statement: Corrects typographical error in first revision.

Response Message:



First Revision No. 46-NFPA 652-2016 [New Section after 3.3.2]

3.3.1 Abort Gate/Damper.

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

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 15 13:58:32 EDT 2016

Committee Statement

Committee Statement: Adds definition for abort gate. Term is used in the new equipment related material proposed for Chapter 8.

Response Message:

**First Revision No. 35-NFPA 652-2016 [Section No. 3.3.19]****3.3.21 Fire Hazard.**

Any situation, process, material, or condition that, ~~on the basis of applicable data~~, can cause a fire or provide a ready fuel supply to augment the spread or intensity of a fire and poses a threat to life or property.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 16:31:21 EDT 2016

Committee Statement

Committee Statement: Removes, "on the basis of applicable data" in response to a Correlating Committee suggestion based on comments received on the same definition on the 654 SD ballot.

Response Message:



First Revision No. 29-NFPA 652-2016 [Section No. 3.3.22]

3.3.24 Fugitive Dusts. ~~(Reserved)~~

Dust that escapes from equipment and containers.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 15:03:00 EDT 2016

Committee Statement

Committee Statement: The technical committee is proposing this new definition for fugitive dust. The term is used in the document and is not currently defined.

Response Message:



First Revision No. 49-NFPA 652-2016 [New Section after 3.3.27.2.1]

3.3.30 K_{St} :

The deflagration index of a dust cloud. [68, 2018]

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 15 15:04:14 EDT 2016

Committee Statement

Committee Statement: Adds definition of K_{st} as it is used throughout the document.

Response Message:

**First Revision No. 62-NFPA 652-2016 [Section No. 3.3.36]****3.3.39** Separation.

~~The interposing of distance~~ A hazard management strategy achieved by the establishment of a distance as required by the standard between the combustible particulate solid process and other operations that are in the same ~~[compartment]~~ room . [654, 2013] [654: 2017]

Submitter Information Verification**Submitter Full Name:** Susan Bershad**Organization:** National Fire Protection Assoc**Street Address:****City:****State:****Zip:****Submittal Date:** Tue Aug 16 16:59:02 EDT 2016**Committee Statement****Committee Statement:** Update of extracted material from 654 to 2017 edition**Response Message:**

**First Revision No. 7-NFPA 652-2016 [Section No. 4.2.4]****4.2.4*** Compliance Options.

The objectives in Section 4.2 shall be ~~achieved~~ deemed to have been met by implementing either of the following ~~means~~ :

- (1) A prescriptive approach in accordance with Chapters 5, 7, 8, and 9 in conjunction with any prescriptive provisions of applicable commodity-specific NFPA standards
- (2) A performance-based approach in accordance with Chapter 6

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 09 10:35:51 EDT 2016

Committee Statement

Committee Statement: This revision was created to address some of the concerns regarding objectives posed by the submitter of PI-28 and the Correlating Committee task group on objectives. The term, "deemed to have been meet", was added to imply that the objectives would be met by implementing the prescriptive requirements or a performance-based approach.

Response Message:

**First Revision No. 33-NFPA 652-2016 [Section No. 5.4.2]**

5.4.2* Determination of Flash-Fire Hazard Potential . (Reserved)

Supplemental Information

<u>File Name</u>	<u>Description</u>
Annex_Material_for_FR-33.docx	

Submitter Information Verification

Submitter Full Name: Susan Bershad
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 10 16:09:06 EDT 2016

Committee Statement

Committee Statement: Change in title of reserved section to reflect more accurately the material that might be added. The committee also added annex material to reflect the current status of the topic.
Response Message:

Write annex material for 5.4.2 Determination of Flash-Fire Potential.

Currently several organizations are in the early stages of developing testing methods to determine the flash-fire potential for combustible dusts. Currently, this document assesses the flash-fire potential to exist concurrently with explosibility, as determined by existing test methods.

**First Revision No. 8-NFPA 652-2016 [New Section after 5.5.3]****5.5.3.2**

Samples that could oxidize or degrade in the presence of air shall be maintained in suitable inert gas or vacuum packaging until tested.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 09 10:59:08 EDT 2016

Committee Statement

Committee Statement: Some materials can oxidize or degrade in air changing their combustibility or explosibility characteristics and should be appropriately preserved between sampling and testing.

Response Message:

[Public Input No. 64-NFPA 652-2016 \[New Section after 5.5.3\]](#)

**First Revision No. 32-NFPA 652-2016 [Section No. 6.6]****6.6 Retained Prescriptive Requirements.**

Portions of a facility designed in accordance with this chapter as an alternative for particular prescriptive requirements shall meet all other relevant prescriptive requirements in this standard .

6.6.1

Portions of a facility design in accordance with Chapter 6 shall also meet the following requirements:

~~Housekeeping in accordance with Section 8.4~~

~~PPE in accordance with Section 8.6~~

~~Management systems in accordance with Chapter 9~~

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 15:35:26 EDT 2016

Committee Statement

Committee Statement: The committee is moving the retained prescriptive requirements to Chapter 9, Management Systems so that any performance-based design needs to meet the management system requirements in Chapter 9. In addition to the housekeeping requirements (Section 8.4), and PPE (Section 8.6), Hot Work (Section 8.5.3) is being moved to Chapter 9. Any performance based design needs to meet all of the Management System requirements in Chapter 9.

Response Message:



First Revision No. 38-NFPA 652-2016 [Section No. 7.1]

7.1* General Requirements.

7.1.1 Responsibility.

The owner/operator of a facility where materials ~~that have been~~ determined to be combustible or explosible in accordance with Chapter 5 are present in an enclosure shall be responsible to ensure a DHA is completed in accordance with the requirements of this chapter.

7.1.2*

The requirements of ~~Chapter 7~~ this chapter shall apply retroactively in accordance with 7.1.2.1 through ~~7.1.2.3~~ and 7.1.2.2.

7.1.2.1

~~For existing processes and facility compartments that are undergoing material modification, the owner/operator shall complete DHAs as part of the project. A DHA shall be completed for all new processes and facility compartments.~~

7.1.2.2*

~~For existing processes and facility compartments that are not undergoing material modification, the owner/operator shall schedule and complete DHAs of existing processes and facility compartments within a 3-year period from the effective date of the standard. A DHA shall be completed by September 7, 2020.~~

7.1.2.3

~~For the purposes of applying the provisions of 7.1.2, material modification shall include modifications or maintenance and repair activities that exceed 25 percent of the original cost. The owner/operator shall demonstrate reasonable progress in each of the 3 years each year in completing DHAs prior to the deadline set in 7.1.2.2.~~

7.1.3

~~For the purposes of applying the provisions of 7.1.2, material modification shall include modifications or maintenance and repair activities that exceed 25 percent of the original cost. The absence of previous incidents shall not be used as the basis for not performing a DHA.~~

7.1.4

~~The DHA shall be reviewed and updated at least every 5 years.~~

Supplemental Information

<u>File Name</u>	<u>Description</u>
Annex_Material_for_FR-38.docx	Revised annex material for 7.1.2.2

Submitter Information Verification

Submitter Full Name: Susan Bershad
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submission Date: Thu Aug 11 15:23:01 EDT 2016

Committee Statement

Committee Statement: The committee revised this section in response to PI - 38, 39, 58, and 57 on Chapter 7, DHA. In response to input from the Correlating Committee to align the schedule for DHA implementation with the industry and commodity-specific standards (5 years versus 3 years), the committee set the date for completion of all DHA to five years from the effective date of the current edition of 652 (September 7th, 2020). They clarified the language indicating that a DHA is required for all new processes and facility compartments. The concept of significant modification triggering a DHA was deleted. By the time this edition of 652 is issued, Industry should be well on their way to implementation. Modifications are covered under the MOC provisions in Chapter 9. The committee also added a requirement that the DHA be reviewed and updated every five years. In addition, the committee emphasized that the absence of previous incidents is not to be used as a basis for not performing a DHA.

Response Message:

Annex Material for FR-38

A.7.1.2.2

The deadline for completing initial DHAs is 5 years after the effective date of the first edition of this standard. The first edition allowed only 3 years for completion of all DHAs. This edition extends this period to 5 years. It is not the intent of this requirement to permit a delay in the completion of all DHA until the ~~third~~ fifth year.

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**First Revision No. 39-NFPA 652-2016 [Section No. 8.1]**

8.1* Inherently Safer Designs. (Reserved)

Supplemental Information

<u>File Name</u>	<u>Description</u>
Annex_Material_for_FR_-39.docx	

Submitter Information Verification

Submitter Full Name: Susan Bershad
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 11 16:20:17 EDT 2016

Committee Statement

Committee Statement: The committee is going to leave this section as reserved. It is setting up a task group for the second draft for development of additional annex material. It is also changing the title of the section to Inherently Safer Design. The original title implies an absolute that cannot be meet (safe design).

Response Message:

Annex Material for FR-39

Facilities should consider alternative processes or raw materials that reduce the need to handle combustible dusts.

Annex Material for FR-39

Facilities should consider alternative processes or raw materials that reduce the need to handle combustible dusts.

**First Revision No. 44-NFPA 652-2016 [New Section after 8.3.3.1.3]****8.3.3.1.4 Systems That Convey Hybrid Mixtures.**

The percentage of the lower flammable limit (LFL) of flammable vapors and the percentage of the minimum explosible concentration (MEC) of combustible dusts, when combined, shall not exceed 25 percent within the airstream, except for systems protected in accordance with [8.7.3.2\(1\)](#) through [8.7.3.2\(6\)](#) .

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 15 10:50:51 EDT 2016

Committee Statement

Committee Statement: Committee generated first revision. Adds requirements from 654 for systems conveying hybrid mixtures.

Response Message:

**First Revision No. 43-NFPA 652-2016 [Section No. 8.3.3.1.4.3]****8.3.3.1.5.3 Shutdown.****(A)**

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

(B)

The requirements of [8.3.3.1.5.3\(A\)](#) ~~8.3.3.1.5.3(A)~~ ~~8.3.3.1.4.3(A)~~ shall not apply during emergency shutdown of the process, such as by activation of an emergency stop button or by activation of an automatic safety interlocking device.

(C)

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

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 15 10:44:29 EDT 2016

Committee Statement

Committee Statement: Committee generated first revision clarifying the requirements for shutdown of pneumatic conveying system.

Response Message:



First Revision No. 40-NFPA 652-2016 [Section No. 8.3.3.3]

8.3.3.3* Specific Requirements for Dust Collection Systems.

8.3.3.3.1*

At each collection point, the system shall be designed to achieve the minimum velocity required for capture, control, and containment of the dust source.

8.3.3.3.2*

The hood or pickup point for each dust source shall have a documented minimum air volume flow based upon the system design.

8.3.3.3.3*

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

8.3.3.3.4*

The addition of branch lines shall not be made to an existing system without first confirming that the entire system will maintain the required and balanced airflow.

8.3.3.3.5*

Dust collection systems that remove material from operations that generate flames, sparks, or hot material under normal operating conditions shall not be interconnected with dust collection systems that transport combustible particulate solids or hybrid mixtures. (See [8.7.4.8-7.48.7.48.7.48.9.4](#) .)

8.3.3.3.6*

The air-material separator (AMS) selected for the system shall be designed to allow for the characteristics of the combustible dust being separated from the air or gas flow.

8.3.3.3.7*

Air-moving devices (AMDs) shall be of appropriate type and sufficient capacity to maintain the required rate of air flow in all parts of the system.

8.3.3.3.8*

Control equipment controlling the operation of the AMS shall be installed in a location that is safe from the effects of a deflagration in the AMS.

Supplemental Information

<u>File Name</u>	<u>Description</u>
Annex_Material_for_FR-40.docx	

Submitter Information Verification

Submitter Full Name: Susan Bershad
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 11 17:45:35 EDT 2016

Committee Statement

Committee Statement: Energy requirement for dust systems are significant and often the single largest power consumer in a facility. Multiple tests has shown that the actual demand for vacuum is often in the 20 to 30% of full open design flows. With new technology it is now possible via a control system to manage where vacuum is needed and at the same time assure that minimum design velocities are maintained to prevent accumulation of dust in the ducting and also maintain minimum design flows at each drop.

The committee is adding annex material to this section that describes variable speed fans and automated dampers.

Response Message:

To be added to the end of the current annex material for 8.3.3.3

Systems have been introduced to incorporate variable speed fans and automated dampers in dust collection systems serving multiple points of use. These systems can reduce energy use by closing unused branch ducts and reducing fan speed while still maintaining design velocities throughout the system. Proper design of these systems is essential to ensure that reliable operation will be achieved under all use conditions. These systems use smaller diameter main ducts to allow for adequate conveying velocity to be maintained under normal use conditions. For use as an add-on to existing dust collection systems the duct system should be redesigned to comply with the requirements of this section. At full use, the smaller main ducts can produce significant pressure drop, and so the fan should be sized appropriately to accommodate both minimum and maximum use conditions. The design should include the following elements, at a minimum:

1. The design should specify the required air volume for each point of use and the minimum velocity for each branch line and duct section between the points of use and the AMS.
2. Monitoring systems should be provided at each drop/branch duct to assure minimum design airflow is maintained when the branch is open.
3. The design should ensure that the required velocity is maintained in all open branches and all duct sections under all use conditions.
4. The controller should automatically open additional points of use or balance air dampers as necessary to always maintain minimum air velocity in all sub branches and the main duct.
5. At startup all gates should be open.
6. The fan package and AMS used in the system should be compatible with the full performance requirements of the system (all sources open to minimum sources open). Improper selection of these items can result in failure to maintain the required duct velocities.
7. Alarms should be provided to alert the appropriate personnel when the system fails to provide the required performance.

**First Revision No. 50-NFPA 652-2016 [New Section after 8.3.5.3]****8.3.4.4 AMS Construction .****8.3.4.4.1**

AMSs shall be constructed of noncombustible materials.

8.3.4.4.2

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

8.3.4.4.3

Where isolated from an AMS by a valve, portable containers intended to receive materials discharged from the AMS shall be permitted to be constructed of combustible material.

8.3.4.4.4

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

8.3.4.4.5

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

8.3.4.4.6

Where provided to permit inspection, cleaning, and maintenance, access doors and access openings shall meet the following requirements:

- (1) They shall be designed to prevent dust leaks.
- (2) They shall be permitted to be used as deflagration vents if they are specifically designed for both purposes.
- (3) They shall be bonded and grounded.
- (4)* If not designed to be used as deflagration vents, they shall be designed to the same strength as the AMS.

8.3.5 Air-Moving Devices (Fans and Blowers).**8.3.5.1**

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

8.3.5.2

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

8.3.5.3*

The requirement of 8.3.5.2 shall not apply to systems protected by an approved explosion prevention or isolation system to prevent the propagation of the flame front from the fan to other equipment in accordance with 8.7.3.2(1) , 8.7.3.2(5) , or 8.7.3.2(6) or 8.7.4 .

8.3.5.4*

Where an AMD is located in the dirty air stream and the dust/air stream concentration is higher than 10 percent of the MEC, fans and blowers shall be of Type A or Type B spark-resistant construction per AMCA 99-0401-86, *Classification for Spark Resistant Construction* , or Type C spark-resistant construction protected with spark detection and extinguishment located downstream of the fan.

8.3.6 Duct Systems.**8.3.6.1**

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

8.3.6.2*

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

8.3.6.3*

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

8.3.6.3.1

Access doors, openings, or removable sections of ductwork shall be provided to allow inspection, cleaning, maintenance, and fire department access.

8.3.6.3.2

Access doors, openings, or removable sections of ductwork shall be designed and maintained to prevent dust leaks and preserve the integrity of the duct.

8.3.6.3.3

Access doors, openings, or removable sections of ductwork that are not specifically designed for deflagration venting shall not be considered as providing that function.

8.3.6.3.4

Access doors, openings, or removable sections of ductwork shall be bonded and grounded.

8.3.7 Sight Glasses.**8.3.7.1**

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

8.3.7.2

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

8.3.7.3

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

8.3.7.4

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

8.3.7.5

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

8.3.7.6

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

8.3.7.7

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

8.3.8 Abort Gates/Dampers.**8.3.8.1 Construction.****8.3.8.1.1**

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

8.3.8.1.2

Abort gates and abort dampers shall be actuated by spark detection or equivalent automatic detection in the duct or pipe upstream of the device.

8.3.8.1.3

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

8.3.8.1.4

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

8.3.8.2 Manual Reset.**8.3.8.2.1**

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

8.3.8.2.2

Automatic or remote reset provisions shall not be permitted.

8.3.8.3 Integrity of Actuation Circuits.**8.3.8.3.1**

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

8.3.8.3.2

When the abort gate is connected via a Class A circuit, supervision shall include the continuity of the abort gate or abort damper releasing device, whether that device is a solenoid coil, a detonator (explosive device) filament, or other such device.

8.3.9 Bulk Storage Enclosures.**8.3.9.1 General.**

8.3.9.1.1

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

8.3.9.1.2*

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

8.3.9.2* Construction.

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

8.3.9.3 Fixed Bulk Storage Location.

8.3.9.3.1

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

8.3.9.3.2

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

- (1) Fixed bulk storage enclosures are protected in accordance with 8.7.3 .
- (2)* Fixed bulk storage enclosures are less than 8 ft ³ (0.2 m ³).

8.3.9.4* Interior Surfaces.

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

8.3.9.5 Access Doors and Access Openings.

Where provided to permit inspection, cleaning, and maintenance, access doors and access openings shall meet the following requirements:

- (1) They shall be designed to prevent dust leaks.
- (2) They shall be permitted to be used as deflagration vents if they are specifically designed for both purposes.
- (3) They shall be bonded and grounded.
- (4) If not designed to be used as deflagration vents, they shall be designed to the same strength as the AMS.

8.3.10* Size Reduction.

Before material is processed by size reduction equipment, foreign materials shall be excluded or removed as required by 8.4.12 .

8.3.11* Particle Size Separation.

8.3.11.1

Particle separation devices shall be designed to control fugitive dust emissions per Section 8.6 .

8.3.11.2

Flexible connectors shall be in conformance with 8.4.7.1.4 .

8.3.12 Pressure Protection Systems.

8.3.12.1 Vacuum Breakers.

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

8.3.12.2 Pressure Relief Devices.

8.3.12.2.1

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

8.3.12.2.2

The requirement of 8.3.12.2.1 shall not apply to systems that are designed for a gauge pressure of less than 15 psi (103 kPa) and are provided with safety interlocks designed to prevent overpressure in accordance with ISA 84.00.01, *Functional Safety: Application of Safety Instrumented Systems for the Process Industry Sector* .

8.3.12.2.3

The requirement of 8.3.12.2.1 shall not apply to systems that are designed for a gauge pressure of less than 15 psi (103 kPa) and are capable of containing the maximum pressure attainable.

8.3.12.2.4*

Pressure relief devices shall not be vented to an area where a dust explosion hazard or dust flash-fire hazard exists, as specified by Section 6.1 of NFPA 654 .

8.3.12.3 Airflow Control Valves.

8.3.12.3.1

Airflow control valves that are installed in pneumatic conveying, dust collection, or centralized vacuum cleaning systems shall provide a tight shutoff.

8.3.12.3.2

Airflow control valves shall be sized to allow passage of the design airflow when the valve is fully open.

8.3.12.3.3

The position of airflow control valves shall be visually indicated.

8.3.12.3.4

Manually adjusted airflow control valves, dampers, or gates, shall have a means of being secured so as to prevent subsequent adjustment or manipulation once the system is set.

8.3.12.3.5

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

8.3.13 Material Feeding Devices.**8.3.13.1 Mechanical Feeding Devices.****8.3.13.1.1**

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

8.3.13.1.2

The alarm shall sound at the operator control station.

8.3.13.2 Drives.**8.3.13.2.1**

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

8.3.13.2.2

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

8.3.14* Bucket Elevators.**8.3.14.1**

Elevator casings, head and boot sections, and connecting ducts shall be designed to control fugitive dust emissions and shall be constructed of noncombustible materials.

8.3.14.2

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

8.3.14.3 Power Cutoff.**8.3.14.3.1**

Each leg shall be provided with a speed sensor device that will cut off the power to the drive motor and actuate an alarm in the event the leg belt slows to 80 percent of normal operating speed.

8.3.14.3.2

Feed to the elevator leg by mechanical means shall be stopped or diverted.

8.3.14.4 Belts.**8.3.14.4.1***

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

8.3.14.4.2*

Belts and lagging shall be fire and oil resistant.

8.3.14.4.3

No bearings shall be located in the bucket elevator casing.

8.3.14.4.4*

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

8.3.14.5 Drive.**8.3.14.5.1***

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

8.3.14.5.2

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

8.3.14.6 Monitors.

8.3.14.6.1

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

8.3.14.6.2

Abnormal conditions shall actuate an alarm requiring corrective action.

8.3.14.6.3

The alarm specified in [8.3.14.6.2](#) shall sound at the operator control station.

8.3.14.7 Emergency Controls.**8.3.14.7.1**

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

8.3.14.7.2

The audible alarm specified in [8.3.14.7.1](#) shall sound at the operator control station.

8.3.15* Enclosed Conveyors.**8.3.15.1 Housing and Coverings.****8.3.15.1.1**

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

8.3.15.1.1.1

Flexible screw conveyors utilizing nonmetal housing shall be permitted to be used, provided the requirements of [8.4.7.1.2](#) are met.

8.3.15.1.2

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

8.3.15.2 Power Shutoff.**8.3.15.2.1***

All conveyors shall be equipped with a device that shuts off the power to the drive motor and sounds an alarm in the event the conveyor plugs.

8.3.15.2.2

The alarm specified in [8.3.15.2.1](#) shall sound at the operator control station, and feed to the conveyor shall be stopped or diverted.

8.3.16 Mixers and Blenders.**8.3.16.1**

Mixers and blenders shall be designed to control fugitive dust emissions.

8.3.16.2

Foreign materials shall be excluded or removed as required by [8.4.12](#).

8.3.16.3

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

Global FR-45

8.3.17* Dryers.**8.3.17.1 Drying Media.****8.3.17.1.1**

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

8.3.17.1.2

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

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

8.3.17.1.3

Dryers shall be constructed of noncombustible materials.

8.3.17.1.4

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

8.3.17.1.5

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.

8.3.17.1.6

Heated dryers shall comply with NFPA 86.

8.3.17.1.7*

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

8.3.17.1.8

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

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

Supplemental Information

<u>File Name</u>	<u>Description</u>
Annex_Material_for_FR-50.docx	

Submitter Information Verification

Submitter Full Name: Susan Bershad
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 16 10:26:11 EDT 2016

Committee Statement

Committee Statement: The technical committee is adding this equipment related material to Chapter 8. Much of the material is from NFPA 654, with edits and revisions. This section contains the fundamental requirements for process equipment for combustible dust.
Response Message:

Annex Material for FR-47

A.8.3.4.4.6.4 See NFPA 68

A.8.3.5.3 These systems include pneumatic conveying systems that require relay (booster) fans and product dryers where the fan is an integral part of the dryer.

A.8.3.5.4 The production of mechanical sparks is only one possible ignition mechanism from a fan or blower. Frictional heat due to contact between moving parts (misalignment) or bearing failure can present an ignition source both in the fan and downstream. Additionally, these failure mechanisms can result in a decrease in airflow through the AMD, which can result in an increase in the combustible dust concentration coincident with the creation of an ignition source.

A. 8.3.6.2 Whenever a duct size changes, the cross-sectional area changes as well. This change in area causes a change in air velocity in the region of the change, introducing turbulence effects. The net result is that a transition (often called a reducer) with an included angle of more than 30 degrees represents a choke when the direction of flow is from large to small and results in localized heating and static electric charge accumulation. When the transition is from small to large, the air velocity drop at the transition is usually enough to cause product accumulation at the transition and the existence of a volume where the concentration of combustible is above the MEC. It is strongly desirable that both situations be avoided.

A.8.3.6.3 Isolation devices in accordance with 8.9.4 are provided to prevent deflagration propagation between connected equipment. According to 8.9.4, additional protection is indicated when the integrity of a physical barrier could be breached through ductwork failure caused by a deflagration outside the equipment. In some cases, a single equipment isolation device can provide protection in both scenarios if that isolation device is installed at the physical barrier. In other cases, this concern can be addressed by strengthening the duct and supports to preclude failure.

A.8.3.9.1.2 Shipping containers can pose a deflagration hazard; however, deflagration protection measures for these units are not always practical. Consideration should be given to deflagration hazards when electing to omit deflagration protection.

A.8.3.9.2 Historically, 8.3.9.2 required that the fixed bulk storage enclosure be constructed of noncombustible materials, which usually meant a metallic material. However, there are some particulates that represent a serious corrosion threat or where contamination from the materials of construction introduces product quality issues, therefore nonmetallic construction is required. The materials of construction for a bulk storage enclosure should not increase the fire protection challenge.

A.8.3.9.3.2 (2) Small containers can pose an explosion hazard; however, explosion protection measures for these units are not always practicable. Consideration should be given to explosion hazards when electing to omit protection.

A.8.3.9.4 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.8.3.10 Size reduction machinery includes equipment such as mills, grinders, and pulverizers.

A.8.3.11 Particle separation devices include screens, sieves, aspirators, pneumatic separators, sifters, and similar devices.

A.8.3.12.2.4 High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust.

A.8.3.14 It is recommended that bucket elevators be located outside of buildings whenever practicable.

A.8.3.14.3.1 Belt alignment monitoring devices are recommended for all elevator legs. Bearing monitoring systems are recommended for head, tail, and bend (knee) pulley bearings on elevator legs.

A.8.3.14.4.2 Where conductive buckets are used on nonconductive belts, bonding and grounding should be considered to reduce the hazards of static electricity accumulation. See NFPA 77 for more information.

A.8.3.14.4.4 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. 8.3.14.5.1 The motor selected should not be larger than the smallest standard motor capable of meeting this requirement.

A. 8.3.15 Explosion protection should be provided when the risk is significant. Where coverings are provided on cleanout, inspection, or other openings, they should be designed to withstand the expected deflagration pressure.

A. 8.3.15.2.1 Explosion protection should be provided when the risk is significant. Where coverings are provided on cleanout, inspection, or other openings, they should be designed to withstand the expected deflagration pressure.

A.8.3.17 Explosion protection should be provided when the risk is significant. Where coverings are provided on cleanout, inspection, or other openings, they should be designed to withstand the expected deflagration pressure.

A.8.2.17.1.7 The maximum safe operating temperature of a dryer is a function of the time–temperature ignition characteristics of the particulate solid being dried as well as of the dryer type. For short time exposures of the material to the heating zone, the operating temperatures of the dryer can approach the dust cloud ignition temperature.

However, if particulate solids accumulate on the dryer surfaces, the operating temperature should be maintained below the dust layer ignition temperature. The dust layer ignition temperature is a function of time, temperature, and the thickness of the layer. It can be several hundred degrees below the dust cloud ignition temperature. The operating temperature limit of the dryer should be based on an engineering evaluation, taking into consideration the preceding factors.

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

**First Revision No. 10-NFPA 652-2016 [Section No. 8.4.2.2.1]****9.4.2.2.1***

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

- (1) Materials of construction shall comply with ~~8.4.7.18.4.6-18.4.7.1~~ 8.4.7.18.4.6.1 .
- (2) Hoses shall be conductive or static dissipative.
- (3) All conductive components, including wands and attachments, shall be bonded and grounded.
- (4) ~~Dust laden air shall not pass through the fan or blower.~~ The fan or blower shall be on the clean side of the primary filtration media or wet separation chamber.
- (5) Electrical motors shall not be ~~in the dust laden air stream.~~ located on the dirty side of the primary filtration media or wet separation chamber unless listed for Class II, Division 1, locations.
- (6)* Where liquids or wet materials are picked up by the vacuum cleaner, paper filter elements shall not be used.
- (7) Vacuum cleaners used for metal dusts shall meet the requirements of NFPA 484.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 09 14:01:28 EDT 2016

Committee Statement

Committee Statement: The committee made changes to avoid the use of the term, "dust laden air", which is not well defined. The committee declined to require that all electric motors be NRTL certified.

Response Message:

[Public Input No. 51-NFPA 652-2016 \[Section No. 8.4.2.2.1\]](#)

**First Revision No. 11-NFPA 652-2016 [Section No. 8.4.2.2.3]****9.4.2.2.3**

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

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 09 14:59:00 EDT 2016

Committee Statement

Committee Statement: This clarifies the original intent of the requirement. It refers to Class II areas where flammable gases are present.

Response Message:

**First Revision No. 12-NFPA 652-2016 [Section No. 8.5.3.1]****9.5.1***

All In addition to the requirements of NFPA 51B , all hot work activities shall comply with the requirements in [9.5.2](#) through [9.5.5](#) .

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 09 16:16:11 EDT 2016

Committee Statement

Committee Statement: Clarifies the relationship between NFPA 51B and the requirements for hot work in NFPA 652

Response Message:

**First Revision No. 31-NFPA 652-2016 [Section No. 8.5.3.6]****9.5.6**

Use of portable electrical equipment that does not comply with the electrical classification of the area where it is to be used shall be authorized and controlled in accordance with the hot work procedure as outlined in Section [9.5](#) .

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 15:12:01 EDT 2016

Committee Statement

Committee Statement: Adds material about portable electrical equipment. This section was previously reserved.

Response Message:

**First Revision No. 13-NFPA 652-2016 [Section No. 8.5.5.2]****8.4.5.2***

Bearings that are directly exposed to a combustible dust atmosphere or that are subject to dust accumulation, either of which poses a deflagration dust ignition hazard, shall be monitored for overheating.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 09 16:22:33 EDT 2016

Committee Statement

Committee Statement: The type of bearing does not matter, this requirement applies to all bearings that are exposed to dust. The committee changed the term deflagration hazard to dust-ignition hazard to more specifically define the risk.

Response Message:

[Public Input No. 35-NFPA 652-2016 \[Section No. 8.5.5.2\]](#)

**First Revision No. 14-NFPA 652-2016 [Section No. 8.5.6.4]****8.4.6.4***

Preventive maintenance programs for electrical equipment and wiring in Class II and Class III locations shall include provisions to verify that dusttight electrical enclosures are not experiencing ~~significant~~ visible dust ~~ingress~~ accumulation .

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 09 16:46:31 EDT 2016

Committee Statement

Committee Statement: The committee agrees that the use of significant is vague and unenforceable. The term was changed to visible.

Response Message:

[Public Input No. 17-NFPA 652-2016 \[Section No. 8.5.6.4\]](#)



First Revision No. 41-NFPA 652-2016 [Section No. 8.8.3]

8.6.3* Fans to Limit Accumulation. (Reserved) Fans for Continuous Dust Control.

It shall be permitted to install and use fans to limit dust accumulation in elevated areas that are otherwise difficult to reach for housekeeping.

8.6.3.1

Fans shall be appropriate for the electrical classification in the areas where they are used.

8.6.3.2

Fans shall be provided in sufficient numbers and locations as required to keep the target areas free of dust accumulations.

8.6.3.3

Fans shall be in operation whenever the equipment generating the dusts is in operation.

8.6.3.4

Fans shall be interlocked to automatically shut down in the event of sprinkler system operation.

8.6.3.5

Dust dispersed by the fans shall not create an explosible dust cloud.

8.6.3.6

The location and range of motion of the fans shall be designed to prevent flow impingement on floors or open equipment containing entrainable dust.

8.6.3.7

Areas that will be swept by the fans shall be free of dust accumulations prior to placing the fans in operation and after every shutdown.

8.6.3.8*

These fans shall be used in conjunction with the housekeeping program to remove dust from the facility.

8.6.3.9*

Concealed spaces, such as areas above suspended ceilings, shall be sealed to prevent dust accumulation.

8.6.3.10

These systems shall not be used where areas above suspended ceilings are used as return air plenums for HVAC systems.

8.6.3.11

Periodic inspections shall be performed to ensure that dust accumulations are maintained below the threshold dust layer thicknesses determined in [9.4.6](#) .

Supplemental Information

<u>File Name</u>	<u>Description</u>
Annex_material_for_FR-41.docx	

Submitter Information Verification

Submitter Full Name: Susan Bershad
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submission Date: Fri Aug 12 14:55:15 EDT 2016

Committee Statement

Committee Statement: The committee has added requirements for fans used to limit accumulation. This section is no longer reserved.

Response Message:

Public Input No. 54-NFPA 652-2016 [Section No. 8.8.3]

Annex material for FR-41

A.8.8.3 These devices are used to continuously dislodge dust from hard to reach building surfaces such as roof structural members, lighting, and elevated ductwork. The fans used typically rotate through a 360° arc and oscillate up and down to keep dust from the surfaces within the reach of the fan discharge. Large rooms require multiple fans for adequate coverage. These systems are most effective for facilities with high ceilings where light, easily entrained dusts or fibers are handled.

A.8.8.3.8 These systems are intended to reduce the housekeeping burden on elevated surfaces. However, they do not remove dust from the facility. The material is simply relocated to lower surfaces where it is easier to clean using standard housekeeping procedures. These systems may increase the required housekeeping frequency on lower surfaces, and may increase the amount of dust carried into the building HVAC system.

A.8.8.3.9 These systems should not be used where they can relocate dust into concealed spaces where the dust can accumulate and pose a deflagration hazard.



First Revision No. 60-NFPA 652-2016 [Section No. 8.9.4]

8.7.4 Equipment Isolation.

8.7.4.1*

Where a dust explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between connected equipment in accordance with NFPA 69.

8.9.4.2

The requirement of [8.9.4.1](#) shall not apply where all the following conditions are met:

~~The material being conveyed is not a metal dust or hybrid mixture.~~

~~The connecting ductwork is smaller than 4 in. (100 mm) nominal diameter.~~

~~The maximum concentration of dust conveyed through the duct is less than 25 percent of the MEC of the material.~~

~~The conveying velocity is sufficient to prevent accumulation of combustible dust in the duct.~~

~~All connected equipment is properly designed for explosion protection by means other than deflagration pressure containment.~~

8.7.4.2

Isolation devices shall not be required where oxidant concentration has been reduced or where the dust has been rendered noncombustible in accordance with [8.7.3.2\(1\)](#) or [8.7.3.2\(6\)](#).

8.7.4.3 Isolation of Upstream Work Areas.

Where a dust explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation from equipment through upstream ductwork to the work areas in accordance with NFPA 69.

Supplemental Information

<u>File Name</u>	<u>Description</u>
Annex_Material_for_FR-60.docx	

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 16 13:39:19 EDT 2016

Committee Statement

Committee Statement: The committee has deleted section 8.9.4.2 and added the material as annex material for 8.9.4.1. Research has shown that flame propagation, although less likely, can occur under all of these conditions and that these systems should not be exempt from the requirements of 8.9.4.1. Additional material has been added to the annex for 8.9.4.1.

This change is being made to be consistent with the changes made to NFPA 654 during the last revision cycle for the 2017 edition.

Response Message:

Annex Material for SR – 60

A.8.9.4.1

The requirement of 8.9.4.1 might not be applicable where all of the following conditions are met:

- (1) The material being conveyed is not a metal dust, ST-3 dust ($K_{St} > 300$ bar·m/s), or hybrid mixture.
- (2) The connecting ductwork is smaller than 4 in. (100 mm) nominal diameter and greater than 15 ft (5 m) in length.
- (3) The conveying velocity is sufficient to prevent accumulation of combustible dust in the duct.
- (4) All connected equipment is properly designed for explosion protection by means other than deflagration pressure containment.
- (5) The upstream work areas do not contain large quantities of dust that can be entrained by a pressure pulse from an explosion in the AMS.

When managing the hazard of propagation via small duct one can develop performance equivalent alternative in accordance with Chapter 6.

Flame spread via propagation inside ducting or piping is somewhat unpredictable for dusts. Tests have shown that propagation is much less likely under certain conditions. Piping less than 4 in. (100 mm) in diameter is less likely to provide a conduit for flame spread than larger diameter piping, although experiments have shown propagation in still smaller diameter piping.

FSA conducted flame propagation tests in a system comprising two interconnected, vented 1 m³ vessels. Experiments were carried out with pipe diameters of 27 mm, 42 mm, 82 mm (all less than 4 in.). Corn starch ($K_{St} = 200$ bar·m/s) and wheat flour ($K_{St} \sim 100$ bar·m/s) were used as fuels. Even with a small pipe diameter of 27 mm and with wheat flour ($K_{St} \sim 100$ bar·m/s) used as test dust, there was a flame propagation through a pipe length of at least 12 m in length.

For interconnected vessels that are relatively close together, measures to reduce P_{red} for each interconnected vessel, taking into account that propagation could occur, would eliminate the need for isolation techniques.

Dense phase pneumatic transfer [air velocities down near 600 fpm (183 m/min), and solids loading ratios greater than 30] is also much less likely to provide a conduit for flame spread propagation than for dilute phase pneumatic transfer [air velocities in the region of 2200 fpm to 3600 fpm (672 m/min to 1098 m/min), and solids loading ratios not greater than 15]. It has been reported by **Pineau** that it is not uncommon for propagation to occur as little few as one time in ten in controlled experiments for 5.9 in. (150 mm) piping even for dilute phase systems. However, recent testing has shown that propagation is more likely with dust concentrations in the lean region. Metal dusts are more likely to propagate deflagrations. For organic dusts, where small diameter pipes with dense phase transfer are utilized, the need for isolation techniques could be obviated if the hazard analysis is acceptable to the AHJ.

Factors for evaluation of isolation between equipment and work areas include, among others, the anticipated P_{red} for the related process equipment, the diameter and length of the connecting air duct, and the quantity of dust in the work area that can be entrained by a pressure pulse from a deflagration in the related process equipment.

See Annex D.1.2.11 for additional information.

**First Revision No. 16-NFPA 652-2016 [New Section after 9.3.2.1]****9.3.3**

A periodic walk-through review of operating areas shall be conducted, on a schedule established by the owner/operator per the requirement in 9.7.3 , to verify that operating procedures and safe work practices are being followed.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 08:47:26 EDT 2016

Committee Statement

Committee Statement: Adds material regarding inspections. In partial response to PI-16 regarding inspections.

Response Message:

**First Revision No. 15-NFPA 652-2016 [Section No. 9.4.6]****9.7.6**

A thorough inspection of the operating area shall take place on an as-needed basis to help ensure periodic walk-through review of operating areas shall be conducted, on a schedule established by the owner/operator per the requirement in [9.7.3](#) , to verify that the equipment is in safe operating condition and that proper work practices are being followed .

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 08:23:46 EDT 2016

Committee Statement

Committee Statement: In response to PI-16 stating that inspections should be performed on a specified schedule. This changes inspections to periodic walk throughs, and directs the user to section 9.4.3 for the establishment of a schedule.

Response Message:

[Public Input No. 18-NFPA 652-2016 \[Section No. 9.4.6\]](#)

**First Revision No. 63-NFPA 652-2016 [Section No. A.3.3.2]****A.3.3.3 Air-Moving Device (AMD).**

An air-moving device is a fan or blower. A general description of each follows:

(1) Fans

- (a) A wide range of devices that utilize an impeller, contained within a housing, that when rotated creates air/gas flow by negative (vacuum) or positive differential pressure.
- (b) These devices are commonly used to create comparatively high air/gas volume flows at relatively low differential pressures.
- (c) These devices are typically used with ventilation and/or dust collection systems.
- (d) Examples are centrifugal fans, industrial fans, mixed or axial flow fans, and inline fans.

(2) Blowers

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

[654,2013 2017]

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submission Date: Tue Aug 16 17:13:15 EDT 2016

Committee Statement

Committee Statement: Update of extracted material from 654 2017 edition.

Response Message:



First Revision No. 64-NFPA 652-2016 [Section No. A.3.3.5]



A.3.3.6 Combustible Dust.

The term *combustible dust* when used in this standard includes powders, fines, fibers, etc.

Dusts traditionally were defined as material 420 μm or smaller (i.e., capable of passing through a U.S. No. 40 standard sieve). For consistency with other standards, 500 μm (i.e., capable of passing through a U.S. No. 35 standard sieve) is now considered an appropriate size criterion. Particle surface area-to-volume ratio is a key factor in determining the rate of combustion. Combustible particulate solids with a minimum dimension more than 500 μm generally have a surface-to-volume ratio that is too small to pose a deflagration hazard. Flat platelet-shaped particles, flakes, or fibers with lengths that are large compared to their diameter usually do not pass through a 500 μm sieve, yet could still pose a deflagration hazard. Many particulates accumulate electrostatic charge in handling, causing them to attract each other, forming agglomerates. Often, agglomerates behave as if they were larger particles, yet when they are dispersed they present a significant hazard. Consequently Therefore, it can be inferred that any particulate that has a minimum dimension less than or equal to 500 μm could behave as a combustible dust if suspended in air or the process specific oxidizer. If the minimum dimension of the particulate is greater than 500 μm , it is unlikely that the material would be a combustible dust, as determined by test. The determination of whether a sample of combustible material presents a flash-fire or explosion hazard could be based on a screening test methodology such as provided in the ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*. Alternatively, and a standardized test method such as ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, could be used to determine dust explosibility. Chapter 5 has additional information on testing requirements. [654,2013 2017]

There is some possibility that a sample will result in a false positive in the 20 L sphere when tested by the ASTM E1226 screening test or the ASTM E1515 test. This is due to the high energy ignition source overdriving the test. When the lowest ignition energy allowed by either method still results in a positive result, the owner/operator can elect to determine whether the sample is a combustible dust with screening tests performed in a larger scale ($\geq 1 \text{ m}^3$) enclosure, which is less susceptible to overdriving and thus will provide more realistic results. [654,2013 2017]

This possibility for false positives has been known for quite some time and is attributed to “overdriven” conditions that exist in the 20 L chamber due to the use of strong pyrotechnic igniters. For that reason, the reference method for explosibility testing is based on a 1 m^3 chamber, and the 20 L chamber test method is calibrated to produce results comparable to those from the 1 m^3 chamber for most dusts. In fact, the U.S. standard for 20 L testing (ASTM E1226) states, “The objective of this test method is to develop data that can be correlated to those from the 1 m^3 chamber (described in ISO 6184-1₇ and VDI 3673)...” ASTM E1226 further states, “Because a number of factors (concentration, uniformity of dispersion, turbulence of ignition, sample age, etc.) can affect the test results, the test vessel to be used for routine work must be standardized using dust samples whose K_{St} and F_{max} parameters are known in the 1 m^3 chamber.” [654,2013 2017]

NFPA 68 also recognizes this problem and addresses it stating that “the 20 L test apparatus is designed to simulate results of the 1 m^3 chamber; however, the igniter discharge makes it problematic to determine K_{St} values less than 50 bar-m/sec. Where the material is expected to yield K_{St} values less than 50 bar-m/sec, testing in a 1 m^3 chamber might yield lower values.” [654,2013 2017]

Any time a combustible dust is processed or handled, a potential for deflagration exists. The degree of deflagration hazard varies, depending on the type of combustible dust and the processing methods used. [654,2013 2017]

A dust deflagration has the following four requirements:

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

[654,2013 2017]

If the deflagration is confined and produces a pressure sufficient to rupture the confining enclosure, the event is, by definition, an “explosion.” [654,2013 2017]

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

- (1) MEC
- (2) MIE
- (3) Particle size distribution
- (4) Moisture content as received and as tested
- (5) Maximum explosion pressure at optimum concentration
- (6) Maximum rate of pressure rise at optimum concentration
- (7) K_{St} (normalized rate of pressure rise) as defined in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*
- (8) Layer ignition temperature
- (9) Dust cloud ignition temperature
- (10) Limiting oxidant concentration (LOC) to prevent ignition
- (11) Electrical volume resistivity
- (12) Charge relaxation time

(13) Chargeability

[654,2013 2017]

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

[654,2013 2017]

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 16 17:24:17 EDT 2016

Committee Statement

Committee Statement: Update of extracted material from the 2017 edition of NFPA 654

Response Message:

**First Revision No. 65-NFPA 652-2016 [Section No. A.3.3.28]****A.3.3.31** Minimum Explosible Concentration (MEC).

Minimum explosible concentration is defined by the test procedure in ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*. MEC is equivalent to the lower flammable limit for flammable gases. Because it has been customary to limit the use of the lower flammable limit to flammable vapors and gases, an alternative term is necessary for combustible dusts. [654,2013 2017]

The MEC is dependent on many factors, including particulate size distribution, chemistry, moisture content, and shape. Consequently, designers and operators of processes that handle combustible particulate solids should consider those factors when applying existing MEC data. Often, the necessary MEC data can be obtained only by testing. [654, 2017]

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 16 17:34:32 EDT 2016

Committee Statement

Committee Statement: Update of extract material to the 2017 edition of 654.

Response Message:



First Revision No. 17-NFPA 652-2016 [Section No. A.5.2]



A.5.2

Test data derived from testing material within a facility Testing actual material from a specific process or area of the facility will result in the most accurate results for the DHA, performance-based design, and hazard management options. Testing is not required to determine whether the material has combustibility characteristics where reliable, in-house, commodity-specific testing data or published data of well-characterized samples (i.e., particle size, moisture content, and test conditions) are available. Published data should be used for preliminary assessment of combustibility only. However, for protection or prevention design methods, the data can be acceptable after a thorough review to ensure that they are representative of owner/operator conditions.

The protection or prevention designs are based on explosivity properties, which can vary based on the specific characteristics of the material. ~~(See 5.2.2 for characteristics that can affect explosibility properties.)~~ Historical knowledge and experience of occurrence or nonoccurrence of process incidents such as flash fires, small fires, sparkling fires, pops, or booms, or evidence of vessel, tank, or container overpressure should not be used as a substitute for hazard analysis. Process incidents are indications of a material or process resulting in combustibility or explosion propensity. Process incidents can be used to guide or select samples for and supplement testing.

The following material properties should be addressed by a DHA for the combustible particulate solids present:

- (1) *Particle Size*. Sieve analysis is a crude and unreliable system of hazard determination. Its greatest contribution in managing the hazard is the ease, economy, and speed at which it can be used to discover changes in the process particulate. In any sample of particulate, very rarely are all the particles the same size. Sieve analysis can be used to determine the fraction that would be generally suspected of being capable of supporting a deflagration.
For a sub-500 micron fraction:
 - (a) Data presented in terms of the percent passing progressively smaller sieves.
 - (b) Particles that have high aspect ratios can produce distorted, ~~nonconservative~~ particle size results.
- (2) *Particle Size Distribution*. The particle size distribution of a combustible particulate ~~solid must be known if the explosion hazard is to be assessed~~ solid is an important parameter in assessing an explosion hazard. Particle size implies a specific surface area (SSA) and affects the numerical measure of other parameters such as MEC, MIE, dP/dt_{max} , F_{max} , and KSt . Particles Spherical particles greater than 500 microns ~~in effective mean particle diameter~~ are generally not considered deflagratory. Most combustible particulate solids include a range of particle sizes in any given sample. The DHA should anticipate and account for particle attrition and separation as particulate is handled.
- (3) *Particle Shape*. Due to particle shape and agglomeration, some particulates cannot be sieved effectively. Particulates with nonspheric or noncubic shapes do not pass through a sieve as easily as spheric or cubic particles. For this purpose, long fibers can behave just as explosively as spherical particulates of a similar diameter. This leads to underestimation of small particle populations and ~~to~~ underassessment of the hazard. Particulates with an aspect ratio greater than 3:1 should be suspect. When particulates are poured into vessels, it is common for the fine particles to separate from the large, creating a deflagration hazard in the ullage space.
- (4) *Particle Aging*. Some combustible particulate solid materials could undergo changes in their safety characteristics due to aging. Changes in morphology and chemical composition, for example, can occur from the time a sample is collected to the time it ~~takes to get that sample into the lab for a test is tested~~. For materials that are known to age, care must be taken in packaging and shipment. The use of vacuum seals, or an inert gas such as nitrogen, could be required to ensure that the tested sample has not changed appreciably due to aging. The lab should be notified in advance of shipment that the material is sensitive to change due to age so that they will know how to handle it and store it until it is tested.
- (5) *Particle Attrition*. The material submitted for testing should be selected to address the effects of material attrition as it is moved through the process. As particulates move through a process they usually break down into smaller particles. Reduction in particle size leads to an increase in total surface area to mass ratio of the particulate and increases the hazard associated with the unoxidized particulate.
- (6) *Particle Suspension*. Particle suspension maximizes the fuel-air interface. It occurs wherever the particulate moves relative to the air or the air moves relative to the particulate, such as in pneumatic conveying, pouring, fluidizing, mixing and blending, or particle size reduction.
- (7) *Particle Agglomeration*. Some particulates tend to agglomerate into clumps. Agglomerating particulates can be more hazardous than the test data imply if the particulate was not thoroughly deagglomerated when testing was conducted. Agglomeration is usually affected by ambient humidity.
- (8) *Triboelectric Attraction*. Particles with a chemistry that allows electrostatic charge accumulation will become charged during handling. Charged particles attract oppositely charged particles. Agglomeration causes particulate to exhibit lower explosion metrics during testing. Humidification decreases the triboelectric effect.
- (9) *Hydrogen Bonding*. Hydrophilic particulates attract water molecules that are adsorbed onto the particle surface. Adsorbed water provides hydrogen bonding to adjacent particles, causing them to agglomerate. Agglomeration causes particulate to exhibit lower explosion metrics during testing. Desiccation reduces this agglomerated effect.
- (10) *Entrainment Fraction*. The calculation for a dust dispersion from an accumulated layer should be corrected for the ease of entrainment of the dust. Fuel chemistry and agglomeration/adhesion forces should be considered. The dispersion is generally a function of humidity, temperature, and time. Particle shape and morphology and effective particle size should be considered.
- (11) *Combustible Concentration*. When particles are suspended, a concentration gradient will develop where concentration varies continuously from high to low. There is a minimum concentration that must exist before a flame front will propagate. This concentration depends on particle size and chemical composition and is measured in ~~grams/cubic meter (ounces/cubic foot)~~ oz/ft^3 (g/m^3). This concentration is called the minimum explosible concentration (MEC). A dust dispersion can come from a layer of accumulated fugitive dust. The concentration attained depends on bulk density of dust layer $\{$ measured in grams/m^3 $\}$ oz/ft^3 (g/m^3 $\}$), layer thickness, and the extent of the dust cloud. Combustible concentration is calculated as follows in Equation A.5.2: $\text{Concentration} = (\text{bulk density}) * \{(\text{layer thickness}) / (\text{dust cloud thickness})\}$

$$\text{Combustible concentration} = \text{Bulk density} \times \frac{\text{Layer thickness}}{\text{Dust cloud thickness}} \quad \text{[A.5.2]}$$

(12) *Competent Igniter*. Ignition occurs where sufficient energy per unit of time and volume is applied to a deflagratory particulate suspension. Energy per unit of mass is measured as temperature. When the temperature of the suspension is increased to the auto-ignition temperature, combustion begins. Ignitability is usually characterized by measuring the minimum ignition energy (MIE). The ignition source must provide sufficient energy per unit of time (power) to raise the temperature of the particulate to its autoignition temperature (AIT).

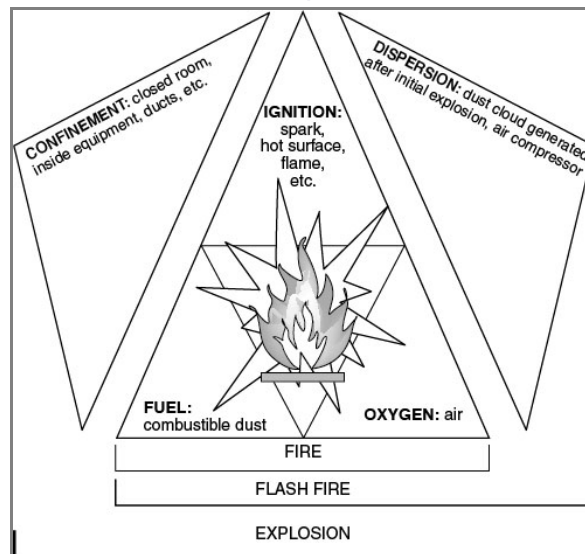
(13) *Dustiness/dispersibility Dispersibility*. Ignition and sustained combustion occurs where a fuel and competent ignition source come together in an atmosphere (oxidant) that supports combustion. The fire triangle represents the three elements required for a fire. Not all dusts are combustible, and combustible dusts exhibit a range in degree of hazard. All combustible dusts can exhibit explosion hazards accompanied by propagation away from the source. In the absence of confinement, a flash-fire hazard results. If confined, the deflagration can result in damaging overpressures. Deflagration is the process resulting in a flash fire or an explosion. The heat flux from combustible metal flash fires is greater than organic materials. The four elements for a flash fire are the following:

- (a) A combustible dust sufficiently small enough to burn rapidly and propagate flame
- (b) A suspended cloud at a concentration greater than the minimum explosion concentration
- (c) The atmosphere to support combustion
- (d) An ignition source of adequate energy or temperature to ignite the dust cloud

The heat flux from combustible metal flash fires is greater than organic materials. (see [Figure A.5.2](#)) – A dust explosion requires the following five conditions (see [Figure A.5.2](#)) :

- (1) A combustible dust sufficiently small enough to burn rapidly and propagate flame
- (2) A suspended cloud at a concentration greater than the minimum explosion concentration
- (3) Confinement of the dust cloud by an enclosure or partial enclosure
- (4) The atmosphere to support combustion
- (5) An ignition source of adequate energy or temperature to ignite the dust cloud

Figure A.5.2 Elements Required for Fires, Flash Fires, and Explosions.



Submitter Information Verification

Submitter Full Name: Susan Bershada

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submission Date: Wed Aug 10 08:57:43 EDT 2016

Committee Statement

Committee Statement: Made revisions to correct typographical errors and clarify some statements.

Response Message:

[Public Input No. 68-NFPA 652-2016 \[Section No. A.5.2\]](#)



First Revision No. 47-NFPA 652-2016 [Section No. A.5.2.2]



A.5.2.2

Such an assessment is to determine whether the dust is a combustible dust and if further assessment is necessary. Data can be from samples within the facility that have been tested or data can be based on whether the material is known to be combustible or not. There are some published data of commonly known materials, and the use of these data is adequate to determine whether the dust is a combustible dust. For well-known commodities, published data are usually acceptable. A perusal of published data illuminates that there is often a significant spread in values. It is useful, therefore, to compare attributes (such as particle distribution and moisture content) in published data with the actual material being handled in the system whenever possible. Doing so would help to verify that the data are pertinent to the hazard under assessment.

Subsection 5.2.2 does not require the user to know all these items for the assessment; rather, it reviews the important items in order to determine whether the material data are representative of the material in the facility. Even test data of material can be different from the actual conditions. Users should review the conditions of the test method as well to ensure that it is representative of the conditions of the facility. Where that is not possible, the use of worst-case values should be selected.

Composition and particle size are two parameters that are useful to identify the number and location of representative samples to be collected and tested. (See Section 5.5 for information on sampling.)

Refer to Tables A.5.2.2(a) through A.5.2.2(k) for guidance only and not as substitutes for actual test data. These tables are not all-inclusive of all combustible dusts and noncombustible dusts. Additionally, material properties and testing methods can provide results that vary from those presented in these tables.

Table A.5.2.2(a) 20-L Sphere Test Data—Agricultural Dusts

<u>Dust Name</u>	<u>P_{max}</u> (bar-g)	<u>(1)</u> <u>K_{St}</u> (bar-m/sec)	<u>Percent</u> <u>Moisture</u>	<u>Particle Size</u> (μm)	<u>Minimum</u> <u>Explosive</u> <u>Concentration</u> (g/m^3)	<u>Percent Greater Than 200 Mesh</u>
Alfalfa	6.7	94	2.1	36	-	-
Apple	6.7	34	-	155	125	-
Beet-root	6.1	30	-	108	125	-
Carrageen	8.5	140	3.8	-	-	98
Carrot	6.9	65	-	29	-	-
Cocoa-bean-dust	7.5	152	-	-	-	-
Cocoa-powder	7.3	128	-	-	-	-
Coconut-shell-dust	6.8	111	6.5	-	-	51
Coffee-dust	6.9	55	4.8	321	-	-
Corn-meal	6.2	47	8.2	403	-	-
Cornstarch	7.8	163	11.2	-	-	-
Cotton	7.2	24	-	44	100	-
Cottonseed	7.7	35	-	245	125	-
Garlic-powder	8.6	164	-	-	-	-
Gluten	7.7	110	-	150	125	-
Grass-dust	8.0	47	-	200	125	-
Green-coffee	7.8	116	5.0	45	-	-
Hops (malted)	8.2	90	-	490	-	-
Lemon-peel-dust	6.8	125	9.5	38	-	-
Lemon-pulp	6.7	74	2.8	180	-	-
Linseed	6.0	17	-	300	-	-
Locust-bean-gum	7.8	78	1.7	-	-	53
Malt	7.5	170	10.5	72	-	-
Oat flour	6.4	81	8.6	-	-	-
Oat grain dust	6.0	14	-	295	750	-
Olive-pellets	10.4	74	-	-	125	-
Onion-powder	9.0	157	-	-	-	-
Parlsey (dehydrated)	7.5	110	5.4	-	26	-
Peach	8.4	81	-	140	60	-
Peanut meal and skins	6.4	45	3.8	-	-	-
Peat	8.3	51	-	74	125	-
Potato	6.0	20	-	82	250	-
Potato flour	9.1	69	-	65	125	-
Potato starch	9.4	89	-	32	-	-
Raw-yucca-seed-dust	6.2	65	12.7	403	-	-

<u>Dust Name</u>	<u>P_{max}</u> (bar g)	<u>(1) K_{St}</u> (bar m/sec)	<u>Percent Moisture</u>	<u>Particle Size</u> (µm)	<u>Minimum Explosive Concentration</u> (g/m ³)	<u>Percent Greater Than 200 Mesh</u>
Rice dust	7.7	118	2.5	-	-	4
Rice flour	7.4	57	-	-	60	-
Rice starch	10.0	190	-	18	-	90
Rye flour	8.9	79	-	29	-	-
Semolina	7.6	79	-	-	-	9
Soybean dust	7.5	125	2.1	-	-	59
Spice dust	6.9	65	10.0	-	-	-
Spice powder	7.8	172	10.0	-	-	-
Sugar (10×)	8.4	154	-	-	-	-
Sunflower	7.9	44	-	420	125	-
Tea	7.6	102	6.3	77	125	-
Tobacco blend	8.8	124	1.0	120	-	-
Tomato	-	-	-	200	100	-
Walnut dust	8.4	174	6.0	-	-	31
Wheat flour	8.3	87	12.9	57	60	6
Wheat grain dust	9.3	112	-	80	60	-
Wheat starch	9.8	132	-	20	60	-
Xanthan gum	7.5	61	8.6	45	-	-

Notes:

Normalized to 1 m³ test vessel pressures, per ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds* →

See also Table F.1(a) in NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, for additional information on agricultural dusts with known explosion hazards.

For those agricultural dusts without known explosion data, the dust should be tested in accordance with ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.

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[61: Table A.6.2.1]

Table A.5.2.2(a) 20-L Sphere Test Data – Agricultural Dusts

<u>Dust Name</u>	<u>Percent Moisture</u>	<u>Median Particle Size (µm)</u>	<u>Percent < 200 Mesh (%)</u>	<u>P_{max}</u> (bar g)	<u>(1) K_{St}</u> (bar m/sec)	<u>Minimum Explosive Concentration</u> (g/m ³)	<u>Minimum Ignition Energy (mJ)</u>
Alfalfa	2.1	36	83	6.7	94		
Angel Food Cake	4.1	41		7.5	132		
Apple		155	9	6.7	34	125	
Beet root		108	26	6.1	30	125	
Carrageenan	3.8		98	8.5	140		
Carrot	4.0	29	76	6.9	65		
Cereal dust (mixed)	4.4	121		6.7	74	265	
Cheesy pasta sauce mix (corn starch and spices)	7.9	<45	68	7.2	99		45
Chili sauce mix (corn starch and spices)	7.0	79	70	6.6	60		74
Cocoa bean dust	2.3	45	100	7.1	133		
Cocoa powder	3.9	194	14	8.0	162	65	100–180
Coconut shell dust	6.5		51	6.8	111		
Coffee dust – coarse particles	4.8	321	0.4	6.9	55		160*
Coffee dust – fine particles	4	40	100	7.7	158		
Corn (maize)	9.0	165		8.7	117	30	>10
Corn meal	8.2	403	0.6	6.2	47		

<u>Dust Name</u>	<u>Percent Moisture</u>	<u>Median Particle Size (µm)</u>	<u>Percent < 200 Mesh (%)</u>	<u>P_{max} (bar g)</u>	<u>(1) K_{St} (bar m/sec)</u>	<u>Minimum Explosive Concentration (g/m³)</u>	<u>Minimum Ignition Energy (mJ)</u>
Cornstarch – coarse particles	2.2	217	0.1	7.9	186		30–60*
Cornstarch – fine particles		11	100	9.5	141	60	
Cotton		44	72	7.2	24	100	
Cottonseed		245	10	7.7	35	125	
Fudge brownie mix	4.8	221		5.8	43		
Garlic powder				8.6	164		
Gluten		150	33	7.7	110	125	
Grass dust		200		8.0	47	125	
Green coffee	5.0	45	81	7.8	116		
Hops (malted)		490	9	8.2	90		
Lemon peel dust	9.5	38	73	6.8	125		
Lemon pulp	2.8	180	17	6.7	74		
Linseed		300		6.0	17		
Locust bean gum	1.7		53	7.8	78		
Malt	10.5	72	54	7.5	170		
Milk powder	3.1	41	88	7.5	145		
Oat flour	4.3	180	0.2	6.8	64		
Oat grain dust		295		6.0	14	750	
Olive pellets				10.4	74	125	
Onion powder				9.0	157		
Parmesan sauce mix (corn starch and spices)	6.7	66	60	6.1	45		62
Parlsey (dehydrated)	5.4		26	7.5	110		
Peach		140	17	8.4	81	60	
Peanut meal and skins	3.8			6.4	45		
Peat		74	48	8.3	51	125	
Potato		82	30	6	20	250	
Potato flakes	8.0	249	7.0	6.2	33		
Potato flour		65	53	9.1	69	125	
Potato starch		32	100	9.4	89		>3200
Raw yucca seed dust	12.7	403	5	6.2	65		
Rice dust	2.5		4	7.7	118		40–120*
Rice flour	12.2	45	100	7.7	140	65	>500
Rice starch		18	90	10	190		
Rye flour		29	76	8.9	79		
Semolina	13.6	57	100	7.0	109		
Snack mix spices	8.3	85		6.8	73		
Soybean dust	2.1		59	7.5	125		
Spice dust	10.0		2	6.9	65		
Spice powder	10.0			7.8	172		
Sugar, fine	1.3	45	100	7.6	117	135	38
Sugar, granulated	2	152	13	6.2	66		
Sugar, powdered	13	45	100	7.0	122		30*
Sunflower		420	10	7.9	44	125	
Tea	6.3	77	53	7.6	102	125	
Tobacco blend	1.0	120		8.0	124		
Tomato		200		1		100	
Walnut dust	6.0		31	8.4	174		
Wheat/rice cereal base	2.8	187		5.7	28	150	

<u>Dust Name</u>	<u>Percent Moisture</u>	<u>Median Particle Size (µm)</u>	<u>Percent < 200 Mesh (%)</u>	<u>P_{max} (bar g)</u>	<u>(1) K_{St} (bar m/sec)</u>	<u>Minimum Explosive Concentration (g/m³)</u>	<u>Minimum Ignition Energy (mJ)</u>
Wheat/rice cereal base regrinds	6.4	217		6.4	29		
Wheat flour	12.9	57	60	8.3	87	60	
Wheat grain dust		80	48	9.3	112	60	
Wheat starch		20		9.8	132	60	25–60*
Xanthan gum	8.6	45	91	7.5	61		
Yellow cake mix	6.1	219		6.3	73		

*The *SFPE Handbook of Fire Protection Engineering*, 4th Edition, Table 3-18.2.

Notes:

- (1) Normalized to 1 m³ test vessel pressures, per ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.
- (2) See also Table F.1(a) in NFPA 68 for additional information on agricultural dusts with known explosion hazards.
- (3) For those agricultural dusts without known explosion data, the dust should be tested in accordance with established standardized test methods.

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[61: Table A.5.2.2]

Table A.5.2.2(b) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen – Agricultural Dusts

<u>Material</u>	<u>Mass Median Diameter (µm)</u>	<u>Minimum Flammable Concentration (g/m³)</u>	<u>P_{max} (bar)</u>	<u>K_{St} (bar-m/s)</u>	<u>Dust Hazard Class</u>
Cellulose	33	60	9.7	229	2
Cellulose pulp	42	30	9.9	62	1
Cork	42	30	9.6	202	2
Corn	28	60	9.4	75	1
Egg white	17	125	8.3	38	1
Milk, powdered	83	60	5.8	28	1
Milk, nonfat, dry	60	—	8.8	125	1
Soy flour	20	200	9.2	110	1
Starch, corn	7	—	10.3	202	2
Starch, rice	18	60	9.2	101	1
Starch, wheat	22	30	9.9	115	1
Sugar	30	200	8.5	138	1
Sugar, milk	27	60	8.3	82	1
Sugar, beet	29	60	8.2	59	1
Tapioca	22	125	9.4	62	1
Whey	41	125	9.8	140	1
Wood flour	29	—	10.5	205	2

[68: Table F.1(a)]

Table A.5.2.2(c) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen – Carbonaceous Dusts

<u>Material</u>	<u>Mass Median Diameter (µm)</u>	<u>Minimum Flammable Concentration (g/m³)</u>	<u>P_{max} (bar)</u>	<u>K_{St} (bar-m/s)</u>	<u>Dust Hazard Class</u>
Charcoal, activated	28	60	7.7	14	1
Charcoal, wood	14	60	9.0	10	1
Coal, bituminous	24	60	9.2	129	1
Coke, petroleum	15	125	7.6	47	1
Lampblack	<10	60	8.4	121	1
Lignite	32	60	10.0	151	1
Peat, 22% H ₂ O	—	125	84.0	67	1

<u>Material</u>	<u>Mass Median Diameter (μm)</u>	<u>Minimum Flammable Concentration (g/m^3)</u>	<u>P_{max} (bar)</u>	<u>K_{St} (bar-m/s)</u>	<u>Dust Hazard Class</u>
Soot, pine	<10	—	7.9	26	1

[68: Table F.1(b)]

Table A.5.2.2(d) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen – Chemical Dusts

<u>Material</u>	<u>Mass Median Diameter (μm)</u>	<u>Minimum Flammable Concentration (g/m^3)</u>	<u>P_{max} (bar)</u>	<u>K_{St} (bar-m/s)</u>	<u>Dust Hazard Class</u>
Adipic acid	<10	60	8.0	97	1
Anthraquinone	<10	—	10.6	364	3
Ascorbic acid	39	60	9.0	111	1
Calcium acetate	92	500	5.2	9	1
Calcium acetate	85	250	6.5	21	1
Calcium stearate	12	30	9.1	132	1
Carboxy- methyl- cellulose	24	125	9.2	136	1
Dextrin	41	60	8.8	106	1
Lactose	23	60	7.7	81	1
Lead stearate	12	30	9.2	152	1
Methyl-cellulose	75	60	9.5	134	1
Paraformaldehyde	23	60	9.9	178	1
Sodium ascorbate	23	60	8.4	119	1
Sodium stearate	22	30	8.8	123	1
Sulfur	20	30	6.8	151	1

[68: Table F.1(c)]

Table A.5.2.2(e) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen – Metal Dusts

<u>Material</u>	<u>Mass Median Diameter (μm)</u>	<u>Minimum Flammable Concentration (g/m^3)</u>	<u>P_{max} (bar)</u>	<u>K_{St} (bar-m/s)</u>	<u>Dust Hazard Class</u>
Aluminum	29	30	12.4	415	3
Bronze	18	750	4.1	31	1
Iron carbonyl	<10	125	6.1	111	1
Magnesium	28	30	17.5	508	3
Phenolic resin	55	—	7.9	269	2
Zinc	10	250	6.7	125	1
Zinc	<10	125	7.3	176	1

[68: Table F.1(d)]

Table A.5.2.2(f) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen(except where noted) – Plastic Dusts

<u>Material</u>	<u>Mass Median Diameter (μm)</u>	<u>Minimum Flammable Concentration (g/m^3)</u>	<u>P_{max} (bar)</u>	<u>K_{St} (bar-m/s)</u>	<u>Dust Hazard Class</u>
(poly) Acrylamide	10	250	5.9	12	1
(poly) Acrylonitrile	25	—	8.5	121	1
(poly) Ethylene (low-pressure process)	<10	30	8.0	156	1
Epoxy resin	26	30	7.9	129	1
Melamine resin	18	125	10.2	110	1
Melamine, molded (wood flour and mineral filled phenol-formaldehyde)	15	60	7.5	41	1
Melamine, molded (phenol-cellulose)	12	60	10.0	127	1

<u>Material</u>	<u>Mass Median Diameter (μm)</u>	<u>Minimum</u>	<u>P_{max}</u>	<u>K_{St}</u>	<u>Dust Hazard Class</u>
		<u>Flammable Concentration (g/m^3)</u>	<u>(bar)</u>	<u>(bar-m/s)</u>	
(poly) Methyl acrylate	21	30	9.4	269	2
(poly) Methyl acrylate, emulsion polymer	18	30	10.1	202	2
Phenolic resin	<10	15	9.3	129	1
	55		7.9	269	2
(poly) Propylene	25	30	8.4	101	1
Terpene-phenol resin	10	15	8.7	143	1
Urea-formaldehyde/ cellulose, molded	13	60	10.2	136	1
(poly) Vinyl acetate/ ethylene copolymer	32	30	8.6	119	1
(poly) Vinyl alcohol	26	60	8.9	128	1
(poly) Vinyl butyral	65	30	8.9	147	1
(poly) Vinyl chloride	107	200	7.6	46	1
(poly) Vinyl chloride/vinyl acetylene emulsion copolymer	35	60	8.2	95	1
(poly) Vinyl chloride/ethylene/vinyl acetylene suspension copolymer	60	60	8.3	98	1

[68: Table F.1(e)]

Table A.5.2.2(g) 20 L and 1 m³ Vessel Test Data, PVC and Copolymer Plastic Resins and Dusts

<u>PVC Resin Sample</u>	<u>GP^a Dispersion</u>	<u>VA^b Copolymer</u>	<u>Baghouse Dust from GP Pipe (as received)</u>	<u>GP Pipe Resin^c</u>	<u>Baghouse Dust from GP Pipe (as received)</u>	<u>GP Pipe Resin (as received)</u>	<u>High Molecular Weight Resin (as received)</u>
	<u>Type of polymerization process</u>						
	<u>Emulsion</u>		<u>Suspension</u>				
Plant designator	A	B	C	C	D	D	E
Test lab	Chilworth	Chilworth	Chilworth	Fike	Chilworth	Chilworth (20 L), Fike (1 m ³)	Fike
Minimum Ignition Energy (MIE), Joules	>10 J	>10 J	>500 mJ	>4653 mJ	>10 J	>10 J	>4468 mJ
Explosion severity, K_{St} (bar-m/s), 20 L test chamber	91	68	84	18	54	9	81
Dust explosion class in 20 L test chamber	ST 1	ST 1	ST 1	ST 1	ST 1	ST 1	ST 1
Explosion severity, K_{St} (bar-m/s), 1 m ³ test chamber	Not tested	Not tested	Not tested	0	Not tested	0	0
Dust explosion class in 1 m ³ test chamber	Not tested	Not tested	Not tested	ST 0	Not tested	ST 0	ST 0
Particle size, avg. (μm)	1 (est.)	N.A.	N.A.	162	N.A.	158	128
Dust fraction (<75 μm , %)	100	100	100	0.1	97	0	0.6

Note: Sponsored by the Vinyl Institute, 1737 King Street, Suite 390, Alexandria, VA 22314.

^aGP: General Purpose

^bVA: Vinyl Acetate

^cDate for MIE and 20 L test were performed by Fike on sample screened to <150 μm and data for 1 m³ tests were performed by Fike on 'as received' sample.

Source: Krock, R., et. al., "OSHA's Combustible Dust National Emphasis Program and Combustibility Characteristics Testing of PVC Resins and PVC Dusts," SPE ANTEC, April, 2012.

Table A.5.2.2(h) Explosibility Properties of Metals

<u>Material</u>	<u>Median Diameter</u> (μm)	<u>K_{st}</u> (bar-m/s)	<u>P_{max}</u> (bar g)	<u>Cloud Ign Temp</u> ($^{\circ}\text{C}$)	<u>MIE</u> (mJ)	<u>MEC</u> (g/m ³)	<u>UN Combustibility Category²</u>	<u>LOC1</u> (v%)	<u>Data Source</u>
Aluminum	~7	—	8	—	—	90			Cashdollar & Zlochower4
Aluminum	22	—	—	—	—	—	—	5 (N)	BGIA3
Aluminum	<44	—	5.8	650	50	45		2 (C)	BuMines RI 6516
Aluminum flake	<44		6.1	650	20	45		<3 (C)	BuMines RI 6516
Aluminum	<10	515	11.2	560	—	60	—	—	BGIA3
Aluminum	580	Not Ignited	—	—	—	—	—	—	BGIA
Beryllium	4	Not Ignited	—	—	—	—	—	—	BuMines RI 6516
Boron	<44	—	—	470	60	<100	—	—	BuMines RI 6516
Boron	~3	—	6.0	—	—	~110		—	Cashdollar & Zlochower
Bronze	18	31	4.1	390	—	750	BZ 4		Eckhoff
Chromium	6	—	3.3	660	5120	770		14 (C)	BuMines RI 6516
Chromium	3	—	3.9	580	140	230	—	—	BuMines RI 6517
Copper	~30	Not Ignited							Cashdollar & Zlochower
Hafnium	~8	—	4.2	—	—	~180	—	—	Cashdollar & Zlochower
Iron	12	50	5.2	580		500	—		Eckhoff
Iron	~45	—	2.1	—	—	~500	—	—	Cashdollar & Zlochower
Iron	< 44	—	2.8	430	80	170	—	13 (C)	BuMines RI 6516
Iron, carbonyl	< 10	111	6.1	310		125	BZ 3		Eckhoff
Manganese	< 44	—	—	460	305	125		—	BuMines RI 6516
Manganese(electrolytic)	16	157	6.3	330	—	—	—	—	Eckhoff
Manganese(electrolytic)	33	69	6.6	—	—	—	—	—	Eckhoff
Magnesium	28	508	17.5	—	—	—	—	—	Eckhoff
Magnesium	240	12	7	760		500	BZ 5		Eckhoff
Magnesium	<44	—	—	620	40	40		—	BuMines RI 6516
Magnesium	<44	—	—	600	240	30	—	<3 (C)	BuMines RI 6516
Magnesium	~16	—	7.5	—	—	55	—	—	Cashdollar & Zlochower
Molybdenum	<10	Not Ignited							Eckhoff
Nickel	~6	Not Ignited							Cashdollar & Zlochower
Niobium	80	238	6.3	560	3	70		6 (Ar)	Industry
Niobium	70	326	7.1	591	3	50		5 (Ar)	Industry
Silicon	<10	126	10.2	>850	54	125	BZ 3		Eckhoff
Silicon, from dust collector	16	100	9.4	800	—	60	—		Eckhoff
Silicon, from filter	<10	116	9.5	>850	250	60	BZ 1		Eckhoff
Tantalum	<44	—	—	630	120	<200		3 (Ar)	BuMines RI 6516
Tantalum	~10		~3			~400			Cashdollar & Zlochower
Tantalum	100	149	6.0	460	<3	160		2 (Ar)	Industry

<u>Material</u>	<u>Median Diameter</u> (μm)	<u>K_{St}</u> (bar-m/s)	<u>P_{max}</u> (bar-g)	<u>Cloud Ign Temp</u> (°C)	<u>MIE</u> (mJ)	<u>MEC</u> (g/m ³)	<u>UN Combustibility Category²</u>	<u>LOC¹</u> (v%)	<u>Data Source</u>
Tantalum	80	97	3.7	540	<3	160		2(Ar)	Industry
Tantalum	50	108	5.5	520	<3	160		2(Ar)	Industry
Tantalum	65	129	5.8	460	<3	160		2(Ar)	Industry
Tantalum	21		5.6	430	<3	125		<2(Ar)	Industry
Tantalum	25			400	>1<3	30		<2(Ar)	Industry
Tin	~8	—	3.3	—	—	~450	—	—	Cashdollar & Zlochower
Titanium	36	Not Ignited				BZ 2			BGIA
Titanium	30	—	—	450	—	—	—		Eckhoff
Titanium	~25		4.7	—	—	70	—		Cashdollar & Zlochower
Titanium	10	—	4.8	330	25	45		6 (N) 4 (Ar)	BuMines RI 6515
Tungsten	≤1	—	~2.3	—	—	~700	—	—	Cashdollar & Zlochower
Tungsten	~10	Not Ignited							Cashdollar & Zlochower
Zinc (from collector)	<10	125	6.7	570	—	250	BZ 3		Eckhoff
Zinc (from collector)	10	176	7.3	—	—	125	BZ 2		Eckhoff
Zinc (from Zn coating)	19	85	6	800	—	—	BZ 2		Eckhoff
Zinc (from Zn coating)	21	93	6.8	790	—	250	—		Eckhoff
Zirconium	<44	—	5.2	20	5	45	—	Ignites in N ₂ & CO ₂	BuMines RI 6516
Zirconium (Zircalloy-2)	50	—	3.0	420	30	—	—	—	BuMines RI 6516

(1) Limiting Oxygen Concentration. The letter in parenthesis in the LOC column denotes the inert gas used to reduce the oxygen concentration as follows: Ar = argon, C = carbon dioxide, N = nitrogen

(2) UN Dust Layer Combustibility Categories are as follows: BZ1 No self-sustained combustion; BZ2 Local combustion of short duration; BZ3 Local sustained combustion, but no propagation; BZ4 Propagating smoldering combustion; BZ5 Propagating open flame; BZ6 Explosive combustion.

(3) BGIA is the GESTIS-DUST-EX database maintained by BGIA-online.hvbg.de

(4) Cashdollar, Kenneth, and Zlochower, Isaac, "Explosion Temperatures and Pressures of Metals and Other Elemental Dust Clouds," *J. Loss Prevention in the Process Industries*, v. 20, 2007.

[484: Table A.1.1.3(b)]

Table A.5.2.2(i) Atomized Aluminum Particle Ignition and Explosion Data

<u>Particle Size</u> (<u>d₅₀</u>) (μm)	<u>BET</u> (m^2/g)	<u>MEC</u> (g/m^3)	<u>P_{max}</u> (psi)	<u>dP/dt_{max}</u> (psi/sec)	<u>K_{St}</u> (bar-m/sec)	<u>Sample Concentration That Corresponds to P_{max} and dP/dt_{max}</u> (g/m^3)		<u>MIE</u> (mJ)	<u>LOC (%)</u>	<u>Most Easily Ignitable Concentration</u> (g/m^3)
Nonspherical, Nodular, or Irregular Powders										
53	0.18	170	123	3,130	59	1,250				
42	0.19	70	133	5,720	107	1,250 (P _{max}), 1,000 (dP/dt _{max})				
32	0.34	60	142	7,950	149	1,250		10		
32	0.58	65	133	8,880	167	750 (P _{max}), 1,500 (dP/dt _{max})		11	Ignition @ 8.0% Nonignition @ 7.5%	1,000
30	0.10	60						10		
28	0.11	55	140	6,360	119	1,000 (P _{max}), 1,250 (dP/dt _{max})		11		
28	0.21	55	146	8,374	157	1,500		11		
9	0.90	65	165	15,370	288	750 (P _{max}), 1,000 (dP/dt _{max})		4		

Particle Size (d ₅₀) (µm)	BET (m ² /g)	MEC (g/m ³)	P _{max} (psi)	dP/dt _{max} (psi/sec)	K _{St} (bar·m/sec)	Sample Concentration That Corresponds to P _{max} and dP/dt _{max} (g/m ³)	MIE (mJ)	LOC (%)	Most Easily Ignitable Concentration (g/m ³)
7	0.74	90	153	17,702	332	1,000 (P _{max}), 500 (dP/dt _{max})	12		
6	0.15	80	176	15,580	292	750	3.5		
6	0.70	75	174	15,690	294	500 (P _{max}), 1,000 (dP/dt _{max})	3		
5	1.00	70					4		
4	0.78	75	167	15,480	291	1,000 (P _{max}), 750 (dP/dt _{max})	3.5		
Spherical Powders									
63	0.15	120	101	1,220	23	1,250 (P _{max}), 1,000 (dP/dt _{max})	N.I.	Ignition @ 8.0% Nonignition @ 7.5%	1,750
36	0.25	60	124	4,770	90	1,250	13		
30	0.10	60	140	5,940	111	1,000	13		
15	0.50	45	148	10,812	203	1,000	7		
15	0.30	55					8		
6	0.53	75	174	16,324	306	750	6		
5	1.30		167	14,310	269	750		Ignition @ 6.0% Nonignition @ 5.5%	750
5	1.00	70	155	14,730	276	1,250	6	Ignition @ 6.0% Nonignition @ 5.5%	1,250
3	2.50	95	165	15,900	298	1,250	4		
2	3.00	130							

For U.S. conversions: 1 m²/g = 4884 ft²/lb; 1 g/m³ = 0.000062 lb/ft³; 1 bar/sec = 14.5 psi/sec; 1 bar·m/sec = 0.226 psi·ft/sec.

BET: surface area per unit mass; MEC: minimum explosible concentration; MIE: minimum ignition energy; LOC: limiting oxygen (O₂) concentration.

Notes:

- The powders tested are representative samples produced by various manufacturers utilizing a variety of methods of manufacture, submitted for testing to a single, nationally recognized testing laboratory, at the same time.
- Data for each characteristic were obtained using the following ASTM methods: MEC: ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*; MIE: ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*; maximum pressure rise (P_{max}), maximum pressure rise rate (dP/dt), and deflagration index (K_{St}): ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*; LOC: ASTM E2079, *Standard Test Methods for Limiting Oxygen (Oxidant) Concentration in Gases and Vapors*.
- Particle size data represent the d₅₀ measurement determined by the laser light-scattering technique.
- Test results represent only the characteristics of those samples tested and should not be considered to be universally applicable. Users are encouraged to test samples of powders obtained from their individual process.

[484: Table A.4.3.1]

Table A.5.2.2(j) Explosion Characteristics of Unalloyed Magnesium Dust in Air [200 mesh (75 µm)]

Explosion Characteristics	Values
Explosibility index ^a	40
Ignition sensitivity ^b	3-0
Explosion severity ^c	7-4
Maximum explosion pressure (gauge)	793 kPa (115 psi)
Maximum rate of pressure rise (gauge)	793 kPa/sec (15,000 psi/sec)
Ignition temperature cloud	1040°F (560°C)
Minimum cloud ignition energy	0.04 J (26.4 W/sec)
Minimum explosion concentration	0.328 kg/m ³ (0.03 oz/ft ³)
Limiting oxygen percent for spark ignition ^d *	—

Note: K_{St} values vary for specific particle sizes.

^a Explosibility index = ignition sensitivity × explosion severity.

^b Ignition sensitivity =

$$\frac{\left[\text{Ignition temp. cloud} \times \text{min. cloud-ignition energy} \right]}{\left[\text{min. explosion concentration (LEL)} \right]}$$

Pittsburgh coal dust

$$\frac{\left[\text{Ignition temp. cloud} \times \text{min. cloud-ignition energy} \right]}{\left[\text{min. explosion concentration} \right]}$$

Sample dust

^c Explosion severity =

$$\left[\text{Max. explosion pressure} \times \text{max. rate of pressure rise} \right]$$

Pittsburgh coal dust

$$\left[\text{Max. explosion pressure} \times \text{max. rate of pressure rise} \right]$$

Sample dust

^d Burns in carbon dioxide, nitrogen, and halons.

[484: Table D.2]

Table A.5.2.2(k) Selected Combustible Dusts Layer or Cloud Ignition Temperature

Chemical Name	CAS No.	NEC Group	Code	Layer or
				Cloud Ignition Temperature (°C)
Acetal, linear		G	NL	440
Acetoacet-p-phenetidine	122-82-7	G	NL	560
Acetoacetanilide	102-01-2	G	M	440
Acetylamino-t-nitrothiazole		G		450
Acrylamide polymer		G		240
Acrylonitrile polymer		G		460
Acrylonitrile-vinyl chloride-vinylidenechloride copolymer (70-20-10)		G		210
Acrylonitrile-vinyl pyridine copolymer		G		240
Adipic acid	124-04-9	G	M	550
Alfalfa meal		G		200
Alkyl ketone dimer sizing compound		G		160
Allyl alcohol derivative (CR-39)		G	NL	500
Almond shell		G		200
Aluminum, A422 flake	7429-90-5	E		320
Aluminum, atomized collector fines		E	CL	550
Aluminum—cobalt alloy (60-40)		E		570
Aluminum—copper alloy (50-50)		E		830
Aluminum—lithium alloy (15% Li)		E		400
Aluminum—magnesium alloy (dowmetal)		E	CL	430
Aluminum—nickel alloy (58-42)		E		540
Aluminum—silicon alloy (12% Si)		E	NL	670
Amino-5-nitrothiazole	121-66-4	G		460
Anthranilic acid	118-92-3	G	M	580
Apricot pit		G		230
Aryl-nitrosomethylamide		G	NL	490
Asphalt	8052-42-4	F		510
Aspirin [acetol (2)]	50-78-2	G	M	660
Azelaic acid	109-31-9	G	M	610
Azo-bis-butyrionitrile	78-67-1	G		350
Benzethonium chloride		G	CL	380
Benzoic acid	65-85-0	G	M	620
Benzotriazole	95-14-7	G	M	440
Beta-naphthalene-axo- dimethylaniline		G		175
Bis(2-hydroxy- 5-chlorophenyl) methane	97-23-4	G	NL	570
Bisphenol-A	80-05-7	G	M	570
Boron, commercial amorphous (85% B)	7440-42-8	E		400

<u>Chemical Name</u>	<u>CAS No.</u>	<u>NEC Group</u>	<u>Code</u>	<u>Layer or Cloud Ignition Temperature (°C)</u>
Calcium silicide		E		540
Carbon black (more than 8% total entrapped volatiles)		F		
Carboxymethyl cellulose	9000-11-7	G		290
Carboxypolymethylene		G	NL	520
Cashew oil, phenolic, hard		G		180
Cellulose		G		260
Cellulose acetate		G		340
Cellulose acetate butyrate		G	NL	370
Cellulose triacetate		G	NL	430
Charcoal (activated)	64365-11-3	F		180
Charcoal (more than 8% total entrapped volatiles)		F		
Cherry pit		G		220
Chlorinated phenol		G	NL	570
Chlorinated polyether alcohol		G		460
Chloroacetoacetanilide	101-92-8	G	M	640
Chromium (97%) electrolytic, milled	7440-47-3	E		400
Cinnamon		G		230
Citrus peel		G		270
Coal, Kentucky bituminous		F		180
Coal, Pittsburgh experimental		F		170
Coal, Wyoming		F		180
Cocoa bean shell		G		370
Cocoa, natural, 19% fat		G		240
Coconut shell		G		220
Coke (more than 8% total entrapped volatiles)		F		
Cork		G		210
Corn		G		250
Corn dextrine		G		370
Corncob grit		G		240
Cornstarch, commercial		G		330
Cornstarch, modified		G		200
Cottonseed meal		G		200
Coumarone-indene, hard		G	NL	520
Crag No. 974	533-74-4	G	CL	310
Cube root, South America	83-79-4	G		230
Di-alpha-cumyl peroxide, 40-60 on CA	80-43-3	G		180
Diallyl phthalate	131-17-9	G	M	480
Dicyclopentadiene dioxide		G	NL	420
Dieldrin (20%)	60-57-1	G	NL	550
Dihydroacetic acid		G	NL	430
Dimethyl isophthalate	1459-93-4	G	M	580
Dimethyl terephthalate	120-61-6	G	M	570
Dinitro-o-toluamide	148-01-6	G	NL	500
Dinitrobenzoic acid		G	NL	460
Diphenyl	92-52-4	G	M	630
Ditertiary-butyl-paracresol	128-37-0	G	NL	420
Dithane m-45	8018-01-7	G		180
Epoxy		G	NL	540
Epoxy-bisphenol A		G	NL	510
Ethyl cellulose		G	CL	320
Ethyl hydroxyethyl cellulose		G	NL	390
Ethylene oxide polymer		G	NL	350

<u>Chemical Name</u>	<u>CAS No.</u>	<u>NEC Group</u>	<u>Code</u>	<u>Layer or Cloud Ignition Temperature (°C)</u>
Ethylene-maleic anhydride copolymer		G	NL	540
Ferbam™	14484-64-1	G		150
Ferromanganese, medium carbon	12604-53-4	E		290
Ferrosilicon (88% Si, 9% Fe)	8049-17-0	E		800
Ferrotitanium (19% Ti, 74.1% Fe, 0.06% C)		E	CL	380
Flax shive		G		230
Fumaric acid	110-17-8	G	M	520
Garlic, dehydrated		G	NL	360
Gilsonite	12002-43-6	F		500
Green base harmon dye		G		175
Guar seed		G	NL	500
Gulonic acid, diacetone		G	NL	420
Gum, arabic		G		260
Gum, karaya		G		240
Gum, manila		G	CL	360
Gum, tragacanth	9000-65-1	G		260
Hemp hurd		G		220
Hexamethylene tetramine	100-97-0	G	S	410
Hydroxyethyl cellulose		G	NL	410
Iron, 98% H2 reduced		E		290
Iron, 99% carbonyl	13463-40-6	E		310
Isotoic anhydride		G	NL	700
L-sorbose		G	M	370
Lignin, hydrolized, wood-type, fine		G	NL	450
Lignite, California		F		180
Lycopodium		G		190
Malt barley		G		250
Manganese	7439-96-5	E		240
Magnesium, grade B, milled		E		430
Manganese vancide		G		120
Mannitol	69-65-8	G	M	460
Methacrylic acid polymer		G		290
Methionine (l-methionine)	63-68-3	G		360
Methyl cellulose		G		340
Methyl methacrylate polymer	9011-14-7	G	NL	440
Methyl methacrylate-ethyl acrylate		G	NL	440
Methyl methacrylate-styrene- butadiene		G	NL	480
Milk, skimmed		G		200
N,N-dimethylthio- formamide		G		230
Nitropyridone	100703-82-0	G	M	430
Nitrosamine		G	NL	270
Nylon polymer	63428-84-2	G		430
Para-oxy-benzaldehyde	123-08-0	G	CL	380
Paraphenylene diamine	106-50-3	G	M	620
Paratertiary butyl benzoic acid	98-73-7	G	M	560
Pea flour		G		260
Peach pit shell		G		210
Peanut hull		G		210
Peat, sphagnum	94114-14-4	G		240
Pecan nut shell	8002-03-7	G		210
Pectin	5328-37-0	G		200
Pentaerythritol	115-77-5	G	M	400

<u>Chemical Name</u>	<u>CAS No.</u>	<u>NEC Group</u>	<u>Code</u>	<u>Layer or Cloud Ignition Temperature (°C)</u>
Petrin acrylate monomer	7659-34-9	G	NL	220
Petroleum coke (more than 8% total entrapped volatiles)		F		
Petroleum resin	64742-16-1	G		500
Phenol formaldehyde	9003-35-4	G	NL	580
Phenol formaldehyde, polyalkylene-p	9003-35-4	G		290
Phenol furfural	26338-61-4	G		310
Phenylbetanaphthylamine	135-88-6	G	NL	680
Phthalic anhydride	85-44-9	G	M	650
Phthalimide	85-41-6	G	M	630
Pitch, coal tar	65996-93-2	F	NL	710
Pitch, petroleum	68187-58-6	F	NL	630
Polycarbonate		G	NL	710
Polyethylene, high pressure process	9002-88-4	G		380
Polyethylene, low pressure process	9002-88-4	G	NL	420
Polyethylene terephthalate	25038-59-9	G	NL	500
Polyethylene wax	68441-04-8	G	NL	400
Polypropylene (no antioxidant)	9003-07-0	G	NL	420
Polystyrene latex	9003-53-6	G		500
Polystyrene molding compound	9003-53-6	G	NL	560
Polyurethane foam, fire retardant	9009-54-5	G		390
Polyurethane foam, no fire retardant	9009-54-5	G		440
Polyvinyl acetate	9003-20-7	G	NL	550
Polyvinyl acetate/alcohol	9002-89-5	G		440
Polyvinyl butyral	63148-65-2	G		390
Polyvinyl chloride-dioctyl phthalate		G	NL	320
Potato starch, dextrinated	9005-25-8	G	NL	440
Pyrethrum	8003-34-7	G		210
Rayon (viscose) flock	61788-77-0	G		250
Red dye intermediate		G		175
Rice		G		220
Rice bran		G	NL	490
Rice hull		G		220
Rosin, DK	8050-09-7	G	NL	390
Rubber, crude, hard	9006-04-6	G	NL	350
Rubber, synthetic, hard (33% S)	64706-29-2	G	NL	320
Safflower meal		G		210
Salicylanilide	87-17-2	G	M	610
Sevin	63-25-2	G		140
Shale, oil	68308-34-9	F		
Shellac	9000-59-3	G	NL	400
Sodium resinate	61790-51-0	G		220
Sorbic acid (copper sorbate or potash)	110-44-1	G		460
Soy flour	68513-95-1	G		190
Soy protein	9010-10-0	G		260
Stearic acid, aluminum salt	637-12-7	G		300
Stearic acid, zinc salt	557-05-1	G	M	510
Styrene modified polyester-glass fiber	100-42-5	G		360
Styrene-acrylonitrile (70-30)	9003-54-7	G	NL	500
Styrene-butadiene latex (>75% styrene)	903-55-8	G	NL	440
Styrene-maleic anhydride copolymer	9011-13-6	G	CL	470
Sucrose	57-50-1	G	CL	350
Sugar, powdered	57-50-1	G	CL	370

<u>Chemical Name</u>	<u>CAS No.</u>	<u>NEC Group</u>	<u>Code</u>	<u>Layer or Cloud Ignition Temperature (°C)</u>
Sulfur	7704-34-9	G		220
Tantalum	7440-25-7	E		300
Terephthalic acid	100-21-0	G	NL	680
Thorium (contains 1.2% O)	7440-29-1	E	CL	270
Tin, 96%, atomized (2% Pb)	7440-31-5	E		430
Titanium, 99% Ti	7440-32-6	E	CL	330
Titanium hydride (95% Ti, 3.8% H)	7704-98-5	E	CL	480
Trithiobisdimethylthio- formamide		G		230
Tung, kernels, oil-free	8001-20-5	G		240
Urea formaldehyde molding compound	9011-05-6	G	NL	460
Urea formaldehyde-phenol formaldehyde	25104-55-6	G		240
Vanadium, 86.4%	7440-62-2	E		490
Vinyl chloride-acrylonitrile copolymer	9003-00-3	G		470
Vinyl toluene-acrylonitrile butadiene	76404-69-8	G	NL	530
Violet 200 dye		G		175
Vitamin B1, mononitrate	59-43-8	G	NL	360
Vitamin C	50-81-7	G		280
Walnut shell, black		G		220
Wheat		G		220
Wheat flour	130498-22-5	G		360
Wheat gluten, gum	100684-25-1	G	NL	520
Wheat starch		G	NL	380
Wheat straw		G		220
Wood flour		G		260
Woodbark, ground		G		250
Yeast, torula	68602-94-8	G		260
Zirconium hydride	7704-99-6	E		270
Zirconium (contains 0.3% O)	7440-67-7	E	CL	330

Notes:

1. Normally, the minimum ignition temperature of a layer of a specific dust is lower than the minimum ignition temperature of a cloud of that dust. Since this is not universally true, the lower of the two minimum ignition temperatures is listed. If no symbol appears in the "Code" column, then the layer ignition temperature is shown. "CL" means the cloud ignition temperature is shown. "NL" means that no layer ignition temperature is available, and the cloud ignition temperature is shown. "M" signifies that the dust layer melts before it ignites; the cloud ignition temperature is shown. "S" signifies that the dust layer sublimates before it ignites; the cloud ignition temperature is shown.

2. Certain metal dusts might have characteristics that require safeguards beyond those required for atmospheres containing the dusts of aluminum, magnesium, and their commercial alloys. For example, zirconium and thorium dusts can ignite spontaneously in air, especially at elevated temperatures.

3. Due to the impurities found in coal, its ignition temperatures vary regionally, and ignition temperatures are not available for all regions in which coal is mined.

[499: Table 5.2.2]

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submission Date: Mon Aug 15 14:42:47 EDT 2016

Committee Statement

**Committee
Statement:
Response
Message:**

Update extract table A.5.2.2 from NFPA 61 to 2017 edition. Delete material on explosion severity and ignition severity since those terms are no longer used in industry.


First Revision No. 48-NFPA 652-2016 [Section No. A.5.4.3.2]
A.5.4.3.2

Testing a worst-case (finest) particle size distribution will provide a conservative determination of the combustibility of the material. (See [Table A.5.4.4.1.](#))

Table A.5.4.3.2 Standard Test Methods to Determine Explosibility Properties

Method	Property
ASTM E2019, <i>Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air</i>	Minimum ignition energy (MIE) of dust cloud in air
ASTM E1491, <i>Standard Test Method for Minimum Autoignition Temperature of Dust Clouds</i>	Minimum ignition temperature (T_{ϵ}) of dust clouds
ASTM E1226, <i>Standard Test Method for Explosibility of Dust Clouds</i>	Maximum explosion pressure (P_{max}), rate and maximum rate of pressure rise (dP/dt), and explosion severity (K_{St})
ASTM E1515, <i>Test Method for Minimum Explosible Concentration of Combustible Dusts</i>	Minimum explosible concentration (MEC)
ASTM E2021, <i>Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers</i>	Minimum ignition temperature (T_{ϵ}) of dust layers
ASTM WK1680, <i>Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds</i>	Limiting oxygen concentration (LOC)

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 15 14:57:31 EDT 2016

Committee Statement

Committee Statement: Deletes table A.5.4.3.2 since the table is duplicated in A.5.4.4.1. Text cross-references table A.5.4.4.1.

Response Message:



First Revision No. 56-NFPA 652-2016 [Section No. A.5.4.4.1]



A.5.4.4.1

Refer to [Table A.5.4.4.1](#) for standard test methods for determining explosibility characteristics of dusts that are used for the DHA, performance-based design method risk assessments, and hazard management of combustible dusts.

Table A.5.4.4.1 Standard Test Methods to Determine Explosibility Properties

Method	Property
ASTM E2019, <i>Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air</i>	Minimum ignition energy (MIE) of dust cloud in air
ASTM E1491, <i>Standard Test Method for Minimum Autoignition Temperature of Dust Clouds</i>	Minimum ignition temperature (T_C) of dust clouds
ASTM E1226, <i>Standard Test Method for Explosibility of Dust Clouds</i>	Maximum explosion pressure (P_{max}), rate and maximum rate of pressure rise (dP/dt), and explosion severity (K_{St})
ASTM E1515, <i>Test Method for Minimum Explosible Concentration of Combustible Dusts</i>	Minimum explosible concentration (MEC)
ASTM E2021, <i>Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers</i>	Minimum ignition temperature (T_C) of dust layers
ASTM WK1680 E2931, <i>Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds</i>	Limiting oxygen concentration (LOC)

ASTM E2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers*, uses a constant temperature hot plate to heat the dust on one side only. Routine tests use a 12.7 mm (0.5 in.) thick layer, which might simulate a substantial build-up of dust on the outside of hot equipment. However, since the ignition temperature normally decreases markedly with increased dust layer thickness, the method allows layer thickness to be varied according to the application.

ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, is used to determine the MIE for any given fuel concentration. The method uses the lowest energy, stored by a capacitor, that when released as a spark will ignite dust cloud-oxidant mixtures. By testing a range of concentrations, the lowest MIE is determined for the optimum mixture. Observed MIE and MIE values are highly sensitive to the test method, particularly the spark electrode geometry and characteristics of the capacitor discharge circuit. Dust ignition energy standard ASTM E2019 describes test methods in current use that have been found to yield comparable results; however, it is a "performance standard," whereby the methodology adopted must produce data within the expected range for a series of reference dusts.

ASTM E1491, *Standard Test Method for Minimum Autoignition Temperature of Dust Clouds*, is used to determine the dust cloud autoignition temperature (AIT). The test involves blowing dust into a heated furnace set at a predetermined temperature. The dust concentration is systematically varied to find the lowest temperature at which self-ignition occurs at ambient pressure, known as the minimum autoignition temperature (MAIT). A visible flame exiting the furnace provides evidence for ignition. Four different furnaces are described in ASTM E1491 (0.27-L Godbert-Greenwald Furnace, 0.35-L BAM Oven, 1.2-L Bureau of Mines Furnace, and 6.8-L Bureau of Mines Furnace). Each yields somewhat different MAIT data, the largest deviations occurring at the greatest MAIT values. However, the lower AIT range is of more practical importance and here the agreement is better (for example $265 \pm 25^\circ\text{C}$ for sulfur).

ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, is used to determine the pressure and rate of pressure rise for suspended combustible dusts. The measurement of the explosibility parameters (P_{max} and K_{St}) requires the reproducible generation of a near homogeneous dust cloud inside a containment vessel of known volume. The explosibility parameters P_{max} (maximum pressure) and K_{St} (maximum rate of pressure rise of the worst-case concentration times the cube root of the test volume) are obtained from such measurements. The determination of a P_{max} and K_{St} for a material first establishes that it is an explosible dust. A bench scale test method in ASTM E1226 involves a vessel at least 20 L in volume in which a dust cloud is formed using the discharge of a small cylinder of compressed air. After a prescribed time delay, the highly turbulent dust cloud is ignited using a strong ignition source of known energy. Pressure is monitored versus time by appropriate transducers and expressed as pressure, P_{ex} , and pressure rate of rise, dP/dt_{ex} . Dust concentration is varied to determine the maxima of both parameters. Particle size and moisture are other variables that must be considered. Particle size should be less than 75 μm ensuring a design that is conservative.

The primary use of the test data P_{max} and K_{St} is for the design of explosion protection systems: venting, suppression, and isolation. Vent designs provide a relief area that will limit damage to the process equipment to an acceptable level. The required vent area is calculated using equations from NFPA 68 and requires knowledge of the process — volume, temperature, operating pressure, design strength, vent relief pressure — and of the fuel, P_{max} and K_{St} . Suppression is the active extinguishment of the combustion and again limits the explosion pressure to an acceptable level. Suppression designs require similar process and hazard data in order to determine the hardware requirements such as size, number, and location of containers, detection conditions, and the final or reduced explosion pressure. Isolation — the prevention of flame propagation through interconnections — requires the same process and hazard data to determine hardware needs and locations. The extent of testing should depend on what the scenario or evaluation such as explosion venting for a dust collector would require K_{St} and P_{max} .

Published data can be used for preliminary assessment only; they should not be used for design. While some materials are well-characterized, tables with explosibility properties often lack specific information such as particle size; therefore, it is recommended that literature values that do not provide particle size information be used with extreme caution. NFPA 61, NFPA 499, NFPA 68, and NFPA 484 have lists of combustible and explosible metals and dusts that are used for guidance or as informational references only and are not to be used for design purposes. Composition, particle size and distribution, and moisture content are the three factors known to strongly influence test results. It is recognized that some industries have historical data on the same material; therefore, the frequency, number, and extent of testing where historical data exists should be made by informed judgment. The owner/operator assumes the risk of using data from tables and historical data. A person or team performing a DHA should scrutinize and make informed judgments about historical and published data and its applicability to the process.

Submitter Full Name: Susan Bershad
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 16 11:51:49 EDT 2016

Committee Statement

Committee Statement: Updates title of ASTM test method. E2931 is now final.
Response Message:

**First Revision No. 1-NFPA 652-2016 [Section No. A.8.4.2.1.2]****A.9.4.2.1.2**

For information on selection of housekeeping methods, refer to 2.2.4 of FM 7-76, Section 2.2.4, Operation and Maintenance Prevention & Mitigation of Combustible Dust Explosions and Fires . Other factors can be considered in the selection of a housekeeping method, such as the effectiveness of or compatibility of certain methods with the material. Cleaning should be comprehensive and should remove dust from the facility versus relocating it to other surfaces in the area. For the purposes of this standard, the concern is about dust that either propagates flame or that can be dispersed by credible disturbances. For accumulations that are not easy to disperse, the fire hazard should be considered (see Section 8.8) .

The accumulation of a dust layer on a surface that is subject to heating (e.g., the surface of a bearing, an electrical motor, or a heater) could insulate the surface, increasing the surface temperature above the equipment "T" rating, to the point where the dust could self-ignite and smolder.

Housekeeping of a dust layer that has self-ignited and started smoldering could result in full-ignition as the dust disperses during the housekeeping process. The burning dust could damage the housekeeping equipment, ignite a larger dust cloud or a flammable gas release in the area, or initiate smoldering in other dust layers. Before performing housekeeping of a dust layer on a potentially hot surface, the dust should be tested to confirm whether self-ignition and smoldering has initiated. Note that housekeeping of dust layers settling after a dust flash-fire should also consider the dust to be smoldering.

Submitter Information Verification

Submitter Full Name: Susan Bershada

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 08 13:21:50 EDT 2016

Committee Statement

Committee Statement: The committee has added additional annex material to clarify the objectives and methods of housekeeping. This is to address concerns raised by the submitter of Public Input no. 9 concerning the relocation of dust during housekeeping activities.

Response Message:

**First Revision No. 34-NFPA 652-2016 [Section No. A.8.5.7.3.1]****A.8.4.7.3.1**

The user should expect that activities such as pouring, unloading, and transferring dusts can lead to the development of an ignitable atmosphere above the settled material in the receiving vessel.

Refer to NFPA 77 for recommendations for how to safely ground personnel.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 16:13:01 EDT 2016

Committee Statement

Committee Statement: Adds reference to NFPA 77 in Annex material

Response Message:

**First Revision No. 53-NFPA 652-2016 [Section No. A.9.7.1]****A.9.10.1**

All plant personnel, including management, supervisors, and maintenance and operating personnel, should be trained to participate in plans for controlling plant emergencies.

The emergency plan should contain the following elements:

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

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

Specialized training for the public fire department(s) and industrial fire brigades can be warranted due to facility specific hazards where the methods to control and extinguish a fire can be outside of their normal arena of traditional fire fighting. *(See OSHA's publication, [Firefighting Precautions at Facilities with Combustible Dust](#), for additional information.)*

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 16 11:34:20 EDT 2016

Committee Statement

Committee Statement: Add a reference to OSHA's document on Firefighting Precautions at Facilities with Combustible Dust.

Response Message:

**First Revision No. 18-NFPA 652-2016 [Section No. B.3.4.3]****B.3.4.3**

The DHA should classify locations into three general categories:

- (1) Not a hazard
- (2) ~~Maybe~~ Might be a hazard
- (3) Deflagration hazard

This will help the owner/operator prioritize management of the hazards. Additionally, it will identify the locations where more information is necessary before a definitive determination can be made.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submission Date: Wed Aug 10 09:12:13 EDT 2016

Committee Statement

Committee Statement: Changed to clarify original intent of material.

Response Message:

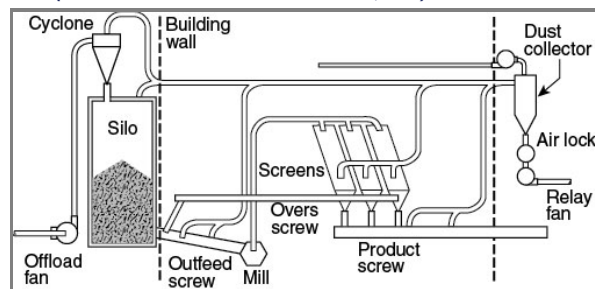


First Revision No. 37-NFPA 652-2016 [Section No. B.4.1]

B.4.1

This example is intended to provide the user with some of the deliberation that can be used in performing a DHA. It is not intended to cover all the methods, situations, and processes that might be encountered in facilities that handle combustible particulate solids. In particular, it does not account for fire hazards that are independent of deflagration hazards. Refer to [Figure B.4.1](#) for the process used in this example.

Figure B.4.1 An Example Process. (Source: J. M. Cholin Consultants, Inc.)



Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 11 09:56:27 EDT 2016

Committee Statement

Committee Statement: This revision clarifies the scope and intent of the example DHA in Annex B. It is not intended to address fire hazards that are independent of deflagration hazards.

Response Message:

**First Revision No. 19-NFPA 652-2016 [Section No. B.4.5.2.4]****B.4.5.2.4**

Are there competent igniters available? Yes. In addition to the igniters identified in [B.4.5.1.4](#), a number of ignition mechanisms are introduced by the fan, including the following examples: -

- (1) Overheated drive bearings (especially the inboard bearing) due to bearing failure from lack of proper lubrication, fatigue, wear, etc.
- (2) Fan impeller/wheel imbalance caused by material accumulation on the blades, bearing failure, wear, etc. (which can result in sparking by housing contact)

Submitter Information Verification

Submitter Full Name: Susan Bershada

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 09:16:01 EDT 2016

Committee Statement

Committee Statement: The examples provided are proven problems that can occur with a material handling (or other industrial) fans. This further assists the reader in understanding the scope of the DHA.

Response Message:

[Public Input No. 40-NFPA 652-2016 \[Section No. B.4.5.2.4\]](#)

**First Revision No. 20-NFPA 652-2016 [Section No. B.4.5.2.5]****B.4.5.2.5**

What hazard management is in place? (See [B.4.5.1.5](#).) It is difficult to apply hazard management to a material conveyance fan. Usually hazard management is applied downstream from the fan. Other hazard management methods would include vibration monitoring (either by personnel on a regular basis or by a monitoring device), temperature monitoring of the drive bearings (by personnel or monitoring device) and amperage monitoring of the drive motor (generally, for a properly operating fan, amperage is directly related to the air mass flow — the higher the amperage, the more air mass flow).

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 09:20:07 EDT 2016

Committee Statement

Committee Statement: Such methods of hazard management have been proven successful in monitoring fan performance and indicating problems before they become a significant hazard.

Response Message:

Public Input No. 41-NFPA 652-2016 [Section No. B.4.5.2.5]

**First Revision No. 21-NFPA 652-2016 [Section No. B.4.5.7 [Excluding any Sub-Sections]]**

While the drawing shows these as separate components, most mills have an integral discharge fan. Most mills in this kind of process require air flow through the mill as part of the milling process. This is typically provided by a fan package (positive or negative pressure, depending upon type of system), which can be integral to the mill or a separate device.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 09:38:38 EDT 2016

Committee Statement

Committee Statement: The previous annex indicated that integral fans are typical for such mills, while it is the submitter's experience, with literally hundreds of such devices and systems, that the fan package is separate nearly all the time and that integral fans are the exception and not the norm.

Response Message:

Public Input No. 42-NFPA 652-2016 [Section No. B.4.5.7 [Excluding any Sub-Sections]]

**First Revision No. 22-NFPA 652-2016 [Section No. B.4.5.7.1]****B.4.5.7.1**

Is the particulate deflagrable (explosible)? It depends. What is the target product particle size? If the mill has $\frac{1}{4}$ in. (6.35 mm) screens, then the unit is receiving large particles and making them less large, but they're still too large to be considered a deflagrable (explosible) particulate. ~~But there are also included fines.~~ If the mill is reducing the particulate down to $250\text{-}\mu$ a fine powder, then ~~all~~ the particulate would probably be considered deflagrable (explosible). ~~Therefore, the determination~~ Determination of whether the particulate in the mill is typically deflagrable is based on the range of particle size exiting the mill. It is usually necessary to submit this material for a go/no-go screening test to determine if the mixture exiting the mill is capable of propagating a deflagration flame front. ~~However, there is a potential that the concentration of fines inside the mill might be higher than the concentration in the product stream due to recirculation within the mill.~~

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 09:52:58 EDT 2016

Committee Statement

Committee Statement: Combustible dust is almost always present in a mill, especially with an integral fan package.

Response Message:

Public Input No. 43-NFPA 652-2016 [Section No. B.4.5.7.1]

**First Revision No. 23-NFPA 652-2016 [Section No. B.4.5.7.2]****B.4.5.7.2**

Is the particulate suspended in air? Yes. Inside the mill and its associated fan, the particulate is in continuous air suspension.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 10:30:41 EDT 2016

Committee Statement

Committee Statement: Fan influence needs to be considered.

Response Message:

[Public Input No. 44-NFPA 652-2016 \[Section No. B.4.5.7.2\]](#)

**First Revision No. 42-NFPA 652-2016 [Section No. B.4.5.7.3]****B.4.5.7.3**

Is there sufficient concentration to support deflagration? This again depends on the test data and a sieve analysis. Because most mills produce fines during the milling process (due to remilling, turbulence, accumulations on internal surfaces, wear, etc.) and it is difficult to be assured that the fines concentrations do not exceed the MEC, it is best to assume sufficient combustible dusts are present. However, some low-speed mills (e.g., shredders) designed to produce only large particles might allow a determination from a sieve analysis and/or testing. Remember that while a sieve analysis is not a definitive criterion for identifying whether a particulate is deflagrable (explosible), it is a very valuable tool for identifying changes that have occurred in the process that signify a change in the hazard associated with the particulate. It is a management of change and safety assessment audit tool.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Mon Aug 15 10:04:09 EDT 2016

Committee Statement

Committee Statement: Mills are not 100% efficient and the milling process is not truly steady-state as it will vary over time (due to material variations, maintenance levels, wear, etc.). Thus, a sieve analysis is only representative of the time it was taken and does not take into account the changes that occur rapidly and/or over time.

Response

Message:

[Public Input No. 45-NFPA 652-2016 \[Section No. B.4.5.7.3\]](#)

**First Revision No. 25-NFPA 652-2016 [Section No. B.4.5.7.4]****B.4.5.7.4**

Are there competent igniters available? Most mills are capable of igniting the material being milled. If tramp metal gets into the process stream, it is likely that the particulate will exit burning, at the very least there is a potential for ignition. Integral or external fan packages also represent additional hazards similar to the fan described in [B.4.5.2.4](#) .

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 10:39:10 EDT 2016

Committee Statement

Committee Statement: The fan package, whether integral to the mill or separate, represents a significant hazard that should also be considered.

Response Message:

[Public Input No. 46-NFPA 652-2016 \[Section No. B.4.5.7.4\]](#)

**First Revision No. 26-NFPA 652-2016 [Section No. B.4.5.7.5]****B.4.5.7.5**

What hazard management is in place? Are there magnetic separators or traps on the infeed to the mill? Is there deflagration suppression and isolation on the mill? Even if the mill is designed to be strong enough to withstand a deflagration within (many are), the deflagration flame front will exit the mill via the infeed and outfeed. What provisions are in place to isolate the mill from the rest of the process? In addition, any integral or external (in-line) fan package would require management such as that discussed in [B.4.5.2.5](#) .

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 10:45:27 EDT 2016

Committee Statement

Committee Statement: The fan package needs to be included in the discussion. Assumes the recommended changes of a previous submission for B.4.5.2.5.

Response Message:

[Public Input No. 47-NFPA 652-2016 \[Section No. B.4.5.7.5\]](#)

**First Revision No. 27-NFPA 652-2016 [Section No. B.4.5.8.4]****B.4.5.8.4**

Are there competent igniters available? Yes. This duct is immediately downstream from the mill or fan package , either of which can be a source of ignition.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 10:46:10 EDT 2016

Committee Statement

Committee Statement: The fan which creates the air flow the the mill must also be considered.

Response Message:

Public Input No. 48-NFPA 652-2016 [Section No. B.4.5.8.4]

**First Revision No. 28-NFPA 652-2016 [Section No. B.4.5.9.2]****B.4.5.9.2**

Is the particulate suspended in air? This depends on the type, make, and model of the screens used. Some agitate the material more aggressively than others. An analysis of the operating screens for the presence of a dust suspension should be undertaken to determine if this criterion is satisfied.

Most screens leak dust into the building interior, and that issue has to be addressed. Without proper dust collection, these devices can emit combustible dusts into the surrounding area.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: [Not Specified]

Street Address:

City:

State:

Zip:

Submittal Date: Wed Aug 10 10:50:22 EDT 2016

Committee Statement

Committee Statement: Without dust collection (usually only on the inlet and outlet portions of the screen to assure the screening process is not inhibited), even with good enclosure of the screen and screening process, dust emissions can and most likely will occur. This is especially true over time when flex connections, seals, etc., tend to wear, etc.

Response Message:

[Public Input No. 49-NFPA 652-2016 \[Section No. B.4.5.9.2\]](#)

**First Revision No. 55-NFPA 652-2016 [Section No. D.1.2.5]****D.1.2.5** ASTM Publications.

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

ASTM E582, *Standard Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures*, 2007.

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

ASTM E1491, *Standard Test Method for Minimum Autoignition Temperature of Dust Clouds*, 2006 (2012).

ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, 2007.

ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, 2003 (2007).

ASTM E2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers*, 2009.

ASTM E2079, *Standard Test Methods for Limiting Oxygen (Oxidant) Concentration in Gases and Vapors*, 2013.

ASTM ~~WK1680~~ E2931, *Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds*, (~~draft under development~~) 2013.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 16 11:47:49 EDT 2016

Committee Statement

Committee Statement: Updates title of ASTM test method. ASTM E2931 is now final.

Response Message:

**First Revision No. 54-NFPA 652-2016 [Section No. D.1.2.10]****D.1.2.9** U.S. Government Publications.

U.S. Government Publishing Office, Washington, DC 20402.

DOE Handbook, *Primer on Spontaneous Heating and Pyrophoricity*, DOE-HDBK-1081-1984.

OSHA 1910.119, "Process Safety Management of Highly Hazardous Chemicals."

OSHA, *Firefighting Precautions at Facilities with Combustible Dust*, 2013.

Title 29, Code of Federal Regulations, Part 1910.119, "Process Safety Management of Highly Hazardous Chemicals."

Title 29, Code of Federal Regulations, Part 1910.146, "Permit-Required Confined Spaces."

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Tue Aug 16 11:41:07 EDT 2016

Committee Statement

Committee Statement: Adds document to list of informational references.

Response Message:



First Revision No. 61-NFPA 652-2016 [Section No. D.1.2.11]

D.2 Informational References.

- [Cozzani, V. and Salzano, E. \(2004\), "The quantitative assessment of domino effects caused by overpressure Part I. Probit models," J. Hazardous Materials, v. A107, pp. 67-80.](#)
- [Davis, S., Hinze, P., Hansen, O., and van Wingerden, K. \(2003\) "Does your facility have a dust problem: Methods for evaluating dust explosion hazards," J Loss Prevention in the Process Industries, v. 24, pp. 837-846.](#)
- [Holbrow, P., Andrews, S. and Lunn, G. \(1996\), "Dust Explosions in Interconnected Vented Vessels," J. Loss Prevention in the Process Industries, v. 9, pp. 91-103.](#)
- [Holbrow, P., Lunn, G. and Tyldesley, A. \(1999\) "Dust explosion protection in linked vessels: guidance for containment and venting," J. Loss Prevention in the Process Industries, v. 12, pp. 227-234.](#)
- [Kosinski, P., and Hoffman, A. \(2006\) "An investigation of the consequences of primary dust explosions in interconnected vessels," J. Hazardous Materials, v. A137, pp. 752-761.](#)
- [Lunn, G., Holbrow, P., Andrews, S. and Gummer, J. \(1996\) "Dust explosions in totally enclosed interconnected vessel systems," J. Loss Prevention in the Process Industries, v. 9, pp. 45-58.](#)
- [Matsuda, T., Toyonaga, K., Nozima, Y., Kobayashi, M., Shimizu, T. \(1982\), "Some observations on dust explosibility in a pneumatic transport system", Journal of Powder & Solids Technology, 6:4, p. 22-28](#)
- [Roser, M. \(1998\), "Investigation of dust explosion phenomena in interconnected process vessels", PhD thesis, Loughborough University](#)
- [Taveau, J., "Myths and Realities of Dust Explosion Propagation in Pipes and Conveying Systems", Process Safety Progress \(to be published\)](#)
- [Valiulis, J., Zalosh, R., and Tamanini, F. \(1999\) "Experiments on the Propagation of Vented Dust Explosions to Connected Equipment," Process Safety Progress, v. 18, pp. 99-100.](#)
- [van der Vort, M, Klein, A, de Maaijer, M., van den Berg, A., van Deursen, J., Versloot, N. \(2007\) "A quantitative risk assessment tool for the external safety of industrial plants with a dust explosion hazard," J Loss Prevention in the Process Industries, v. 20, pp. 375-386.](#)
- [van Wingerden, K. and Alfert, F. \(1992\) "Dust Explosion Propagation in Connected Vessels," VDI Betichte, Nr 975, 507.](#)
- [Vogl, A., \(1996\) "Flame Propagation in Pipes of Pneumatic Conveying Systems and Exhaust Equipment," Process Safety Progress, v. 15, pp. 216-226.](#)
- [Vogl, A. and Radant, S. \(2001\) "Explosion propagation through thin pipes," FSA Project 05- 9903, VDI Report 1601 \(in German\).](#)

Supplemental Information

<u>File Name</u>	<u>Description</u>
References.docx	For staff use.

Submitter Information Verification

Submitter Full Name: Susan Bershad
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 16 16:22:02 EDT 2016

Committee Statement

Committee Statement: Additional references have been added to provide additional information for FR-60.
Response Message:

**First Revision No. 66-NFPA 652-2016 [Section No. D.3]****D.3** References for Extracts in Informational Sections.

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

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2013 2018 edition.

NFPA 484 , *Standard for Combustible Metals* , 2018 edition.

NFPA 499 , *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas* , 2017 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2013 2017 edition.

Submitter Information Verification

Submitter Full Name: Susan Bershad

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 18 11:08:17 EDT 2016

Committee Statement

Committee Statement: Updates edition date for extracted material in first draft

Response Message: