Public Input No. 32-NFPA 660-2025 [Global Input]

Section/Paragraph Reference:
Annex A, add new A.x.x

Proposed Annex Text:

A.x.x Application of Autonomous Multidomain Safety Systems in Combustible Dust Environments.
Facilities handling combustible dust may benefit from autonomous multidisciplinary safety systems such as AIMSAFEGURD™, which provide real-time monitoring of **airborne dust concentrations, smoke, flame, toxic gases, oxygen depletion, pressure rise, and electrical overheating**.

AIMSAFEGURD™ enhances combustible dust safety by:
– Detecting **incipient ignition sources** through thermal and electrical monitoring.
– Executing **triple disconnection (MV/LV/DC)** to eliminate ignition energy in hazardous zones.
– Performing **super-fast damper and valve shutdown** to control dust migration through ducts and conveyors.
– Monitoring **mechanical systems** (fans, mills, dust collectors) for abnormal vibration, friction, or heat.
– Using **AI-driven hazard prediction** to anticipate conditions leading to deflagration or explosion.
– Logging all events for compliance with OSHA, NFPA, and insurance requirements.

Such systems can serve as supplemental tools to improve worker safety and reduce the likelihood of catastrophic dust explosions.

Statement of Problem and Substantiation:

NFPA 660 provides requirements for managing combustible dust hazards but does not reference autonomous multi-sensor systems capable of continuous real-time hazard evaluation. Hazards include **dust accumulation, mechanical friction, static discharge, electrical arcing, and toxic atmospheres**.
AIMSAFEGURD™ addresses these risks by combining real-time dust monitoring, rapid ignition source isolation, mechanical oversight, and predictive analytics. Including annex material raises awareness of emerging technologies without altering prescriptive requirements.

Statement of Problem and Substantiation for Public Input

NFPA 660 provides requirements for managing combustible dust hazards but does not reference autonomous multi-sensor systems capable of continuous real-time hazard evaluation. Hazards include dust accumulation, mechanical friction, static discharge, electrical arcing, and toxic atmospheres. AIMSAFEGURD™ addresses these risks by combining real-time dust monitoring, rapid ignition source isolation, mechanical oversight, and predictive analytics. Including annex material raises awareness of emerging technologies without altering prescriptive requirements.

Submitter Information Verification

Submitter Full Name: Oleg Tsyganok
Organization: AIM-SAFENET
Affiliation: NFPA Member #1114021697

Street Address:
City:
State:
Zip:
Submittal Date: Fri Sep 26 21:09:40 EDT 2025
Committee: CMD-FUN

Committee Statement

Resolution: Endorsement of proprietary products or services in NFPA standards is prohibited by Section 3.2 of the ANSI/NFPA Patent Policy & Commercial Terms and Conditions (available at nfpa.org/regs). The submitter should clarify whether this technology has been subject to a third-party conformity assessment to verify performance against a known performance standard, and whether there is an independent listing standard that this product meets. Annex text has been proposed, but the submitter has not indicated which requirement in the standard this annex material should be associated with.

Public Input No. 50-NFPA 660-2025 [Global Input]

Throughout NFPA 660, and with a focus on Ch. 22, the standard focuses on spark-resistant and electrically conductive tools like scoops.

There is no evidence that a brush discharge can ignite combustible dust, even with a very low MIE (1 mj). In some real world applications, the margin for human error to adequately bond and ground scoops during manual dust clean up is riskier than allowing for nonconductive scoops. The lack of adequate bonding/grounding for conductive scoops allows for a potential spark discharge to build up and ignite dust. The use of nonconductive scoops mititages the risk of human error since bonding/grounding is not required, and mitigates the potential fire since the potential for a brush discharge has shown no evidence of igniting combustible dusts, even with very low MIEs (1 mJ).

Reference: Paper Helsinki Brushg Discharge 01 Korr Glor and Glo_M ESD Hazards by GLOR

Requesting a task group to review the implications of Helsinki paper relative to NFPA 660.

Statement of Problem and Substantiation for Public Input

Inconsistency between NFPA 660 and latest evidence based research regarding brush discharges and their ability to create a fire hazard associated with combustible dust.

Submitter Information Verification

Submitter Full Name: Laura Jacobsen
Organization: The Boeing Company
Street Address:
City:
State:
Zip:
Submittal Date: Wed Dec 17 17:02:04 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: The Fundamentals committee agrees with forming a task group to review this issue, but no specific changes to the standard have been proposed at this time. See meeting minutes for Task Group information.

Public Input No. 1-NFPA 660-2025 [Section No. 1.3.9]

1.3.9

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, except where covered in Chapter 22

(5) ~~Such materials stored or used in farm buildings or similar occupancies for on-premises agricultural purposes~~

Additional Proposed Changes

File Name	Description	Approved
Public_comment_text.docx	Public comment text from submitter	

Statement of Problem and Substantiation for Public Input

1.3.9
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, except where covered in Chapter 22
5. Such materials stored or used in farm buildings or similar occupancies for on-premises agricultural purposes

Submitter's comments
Item 5 above should be deleted to allow agreement with 1.3.5, which states, "This standard shall apply to the production, processing, handling, and storage of agricultural and food products..." 1.3.5(9) excludes "Such materials stored or used in farm buildings or similar occupancies for on-premises agricultural purposes." By stating that NFPA 660 doesn't apply to such materials STORED or USED, but earlier stating in 1.3.5 that the standard applies to the production, processing, handling, and storage...", the committee is allowing confusion. On any farm, large amounts of "Such materials" that will produce combustible dust when "stored or used" will be present. "Used" can include pouring, mixing, and conveying, where combustible dusts are readily generated.
It appears that the committee is trying, in item (5) above, to exclude small amounts of materials. Whatever the intent, the committee should clarify it in 1.3.9(5) (e.g., by including a threshold volume, threshold Kst, threshold MIE, etc.) or delete 1.3.9(5).

Submitter Information Verification

Submitter Full Name: Thomas McKeon
Organization: SEK Safety & Risk Management
Street Address:
City:

State:
Zip:
Submittal Date: Mon Mar 24 20:52:07 EDT 2025
Committee: CMD-FUN

Committee Statement

Resolution: The Technical Committee on Agricultural Dust has discussed this issue at length and has determined that a threshold level to define a farm building cannot be established due to the extensive range of storage and use methods that exist in farm scenarios. The Fundamentals committee does not believe that this conflicts with 1.3.5, rather it is an exemption to the broader scope of 1.3.5.

1.3.9

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, except where covered in Chapter 22
5. ~~Such materials stored or used in farm buildings or similar occupancies for on-premises agricultural purposes~~

Submitter's comments

Item 5 above should be deleted to allow agreement with 1.3.5, which states, "This standard shall apply to the production, processing, handling, and storage of agricultural and food products..." 1.3.5(9) excludes "Such materials stored or used in farm buildings or similar occupancies for on-premises agricultural purposes." By stating that NFPA 660 doesn't apply to such materials STORED or USED, but earlier stating in 1.3.5 that the standard applies to the production, processing, handling, and storage...", the committee is allowing confusion.

On any farm, large amounts of "Such materials" that will produce combustible dust when "stored or used" will be present. "Used" can include pouring, mixing, and conveying, where combustible dusts are readily generated.

It appears that the committee is trying, in item (5) above, to exclude small amounts of materials. Whatever the intent, the committee should clarify it in 1.3.9(5) (e.g., by including a threshold volume, threshold Kst, threshold MIE, etc.) or delete 1.3.9(5).

Public Input No. 174-NFPA 660-2026 [Section No. 2.3.3]

2.3.3 ASTM Publications.

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

ASTM D378, *Standard Test Methods for Rubber (Elastomeric) Conveyor Belting, Flat Type*, 2010, reapproved 2016.

ASTM E11, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves*, ~~2022~~ 2024 .

ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*, ~~2022~~ 2024c .

ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, 2019, reapproved 2025 .

ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, 2014, reapproved 2022.

ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, 2003, reapproved ~~2019~~ 2025 .

ASTM F1002, *Standard Performance Specification for Protective Clothing and Materials for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards*, 2015, reapproved 2021.

ISO/ASTM 52900, *Additive Manufacturing — General Principles — Fundamentals and Vocabulary*, 2021.

Statement of Problem and Substantiation for Public Input

date updates

Submitter Information Verification

Submitter Full Name: Marcelo Hirschler
Organization: GBH International
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jan 06 19:35:15 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: FR-48-NFPA 660-2026
Statement: Updating references to the most recent editions.

Public Input No. 43-NFPA 660-2025 [New Section after 3.3]

TITLE OF NEW CONTENT

See Attached File

Additional Proposed Changes

File Name	Description	Approved
660_CMD-FUN_PC_232_Rejected_but_Held.pdf	NFPA 660 CMD-FUN PC 232	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as "Reject but Held" in the Public Comment No. 232 of the F2024 Second Draft Report for NFPA 660 per Regs. at 4.4.8.3.1.

NFPA 660 uses various terms to describe fire and explosion hazards. Unfortunately the mixing of these terms creates confusion on which hazard is being discussed. This new section provides a set of definitions that should be used throughout the standard to identify fire and explosion hazards. The terminology is intended to be consistent with how these hazards are identified in other NFPA standards and in fire engineering books.

Submitter Information Verification

Submitter Full Name: NFPA Holds
Organization: Holds
Street Address:
City:
State:
Zip:
Submittal Date: Tue Dec 16 16:18:53 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: CI-54-NFPA 660-2026

Statement: This was a Public Comment held during the last revision cycle. Coordination of these terms throughout NFPA 660 is needed, but the Task Group on Hazard/Hazard Area Definitions created by the Correlating Committee in July 2024 has not met to discuss recommended text. The task group should continue their work and present proposed text to the Correlating Committee for consideration in the First Draft Report.

Public Comment No. 232-NFPA 660-2024 [New Section after 3.3]

3.3.38* Dust Hazards

A.3.3.38 Dust Hazards

By its chemical nature combustible dust can be oxidized and generate heat and light. This process is called combustion. The combustion process can exist as a diffusion flame where the fuel and oxidizer are initially separated, and the oxidation reaction occurs in the zone where they mix. Combustion can also occur when the fuel and oxidizer are intimately mixed before ignition. This is referred to as a pre-mixed flame.

Combustion fed by a diffusion process can generate either smoldering combustion or flaming combustion. Smoldering combustion occurs at a slow rate and at lower temperatures when oxygen directly attacks the surface of a condensed phase fuel. This process can occur in finely divided fuels with large surface areas per unit mass or in porous fuels such as cellulose materials. Smoldering can evade detection for some time but when the surface is disturbed there is a transition to flaming combustion.

Flaming combustion is commonly seen as a fire where a solid or liquid fuel is pyrolyzed into flammable gases that burn where the gas and oxidizer mix. The speed of this process is controlled by the rate of pyrolysis of the fuels surface and rate of mixing of the gaseous fuel and oxidizer. In cases where the fuel and oxidizer are mixed before ignition, the speed of the combustion process is controlled by the chemical kinetics of the oxidization reaction and will be much faster than a diffusion flame and can produce a pressure rise within a fixed volume due to the fast rise in gas temperature.

Pre-mixed fuel-oxidizer mixtures are characterized by the speed of the flame front though the mixture. When the combustion zone is propagating at a velocity greater than the speed of sound in the unreacted medium it is referred to as a detonation. This type of event cannot be controlled without extreme measures. Most combustible dusts do not have flame speeds that can produce a detonation.

When the combustion zone is propagating at a velocity less than the speed of sound in the unreacted medium, it is referred to as a deflagration. Deflagrations are expected to occur if a suspended cloud of combustible dust above its minimum explosible concentration (MEC) is ignited. When a deflagration occurs within a fixed volume and the pre-mixed fuel-oxidizer mixture occupies enough of the volume, the gas temperature within that volume will quickly rise resulting in a fast pressure rise. If the fixed volume is not designed to provide a means to control the generated pressure, high temperature gas, and flame, the structure will fail. This fixed volume can occur in enclosed equipment or enclosed buildings. NFPA 68 and NFPA 69 provide generally accepted methods of controlling this type of event, considered to be an explosion.

If the pre-mixed fuel-oxidizer mixture occupies a limited percentage of the volume or is generated over a longer time-period (i.e., dust being entrained into a pressure wave moving through a building), the deflagration will still generate a large flame, but the overall pressure rise is less likely to cause severe structural damage to the fixed volume. This type of event will still produce a significant thermal load on anything inside the volume. As the fuel amount increases, the duration of the thermal load will increase. Personal protective equipment will likely provide some protection against a local, short duration flash fire but may not provide adequate protection against a long duration flash fire.

Combustible dusts are capable of producing smoldering combustion hazards, flaming combustion hazards, flash fire (local or wide area) hazards, equipment explosion hazards, or building explosion hazards. Figure A.3.3.38 provides an overview of the various combustion processes and associated hazards.

Figure A.3.3.38. Overview of Combustion Processes and Associated Hazards (See Attached File)

3.3.38.1 Fire Hazard

Any situation, process, material, or condition that can provide fuel for flaming or smoldering combustion. (CMD-FUN)

3.3.38.2 Local Area Flash Fire Hazard

Any situation that produces a suspended cloud of combustible dust occupying a limited volume of a building or structure, that will support a deflagration within the cloud. The volume of the pre-mixed combustible dust-air mixture is too small to generate damaging over pressures or extended combustion times within the building or structure. This scenario is commonly tied to the release of dust from dust handling equipment after an equipment explosion . Personal protective equipment is expected to offer some protection against this event. (CMD-FUN)

3.3.38.3 Building Compartment Flash Fire Hazard

Any situation that produces a suspended cloud of combustible dust occupying a large volume of a building/structure or can be fed by the entrainment of dust accumulated on building structures over a wide area that will support a deflagration within the building/structure. The volume of the pre-mixed combustible dust-air mixture, while large, is too small to generate damaging overpressures but will produce a long duration thermal load within the building. This scenario can be initiated by an explosion within dust handling equipment that vents into a building or structure with dust accumulations on structural elements. Personal protective equipment may not offer adequate protection against this event. (CMD-FUN)

3.3.38.4 Building Explosion Hazard

Any situation that produces a suspended cloud of combustible dust occupying a large volume of a building/structure or can be fed by the entrainment of dust accumulated on building structures over a wide area that will support a deflagration and generate damaging overpressure within the building/structure. The volume of the pre-mixed combustible dust-air mixture is large enough to produce overpressures that will cause the failure of building elements. This type of hazard is possible in building volumes that contain one or all the following:

(1) **Combustible dust suspended within the building volume.**

(2) **Combustible dust deposits on building elements or equipment.**

(3) **Combustible dust handling equipment located inside a building that is not properly protected against an explosion. (CMD-FUN)**

3.3.38.5 Equipment Explosion Hazard

Any dust handling equipment that can produce a suspended cloud of combustible dust capable of supporting a deflagration. The volume of the pre-mixed combustible dust-air mixture will generate overpressures that will cause the equipment to fail and release pressure, high temperature gas, flame, and unburned dust. The released unburnt dust can then combust outside the equipment. This type of hazard can exist in any piece of equipment handling combustible dust. (CMD-FUN)

Additional Proposed Changes

File Name	Description	Approved
Figure_A.3.3.38.docx	Figure A.3.3.38	

Statement of Problem and Substantiation for Public Comment

NFPA 660 uses various terms to describe fire and explosion hazards. Unfortunately the mixing of these terms creates confusion on which hazard is being discussed. This new section provides a set of definitions that should be used throughout the standard to identify fire and explosion hazards. The terminology is intended to be consistent with how these hazards are identified in other NFPA standards and in fire engineering books.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 233-NFPA 660-2024 [Section No. 3.3.47]	
Public Comment No. 234-NFPA 660-2024 [Section No. 3.3.27]	
Public Comment No. 237-NFPA 660-2024 [Section No. 3.3.28]	
Public Comment No. 238-NFPA 660-2024 [Section No. 3.3.37]	
Public Comment No. 239-NFPA 660-2024 [Section No. 3.3.43]	
Public Comment No. 240-NFPA 660-2024 [Section No. 3.3.51]	
Public Comment No. 241-NFPA 660-2024 [Section No. 3.3.52]	
Public Comment No. 242-NFPA 660-2024 [Section No. A.3.3.47]	
Public Comment No. 243-NFPA 660-2024 [Section No. A.3.3.27]	
Public Comment No. 244-NFPA 660-2024 [Section No. A.3.3.28.1]	
Public Comment No. 245-NFPA 660-2024 [Section No. A.3.3.28.2]	
Public Comment No. 246-NFPA 660-2024 [Section No. A.3.3.37]	
Public Comment No. 247-NFPA 660-2024 [Section No. A.3.3.51]	
Public Comment No. 248-NFPA 660-2024 [Section No. A.3.3.52]	
Public Comment No. 249-NFPA 660-2024 [Section No. A.4.1]	
Public Comment No. 250-NFPA 660-2024 [Section No. 4.2.5]	
Public Comment No. 251-NFPA 660-2024 [Section No. 4.2.6]	
Public Comment No. 252-NFPA 660-2024 [Section No. 6.3.1]	
Public Comment No. 253-NFPA 660-2024 [Section No. 7.2.1]	
Public Comment No. 255-NFPA 660-2024 [Section No. A.7.2.1]	
Public Comment No. 256-NFPA 660-2024 [Section No. 7.2.2]	
Public Comment No. 257-NFPA 660-2024 [Section No. 7.3.1]	
Public Comment No. 258-NFPA 660-2024 [Section No. 7.3.3.3]	
Public Comment No. 259-NFPA 660-2024 [Section No. 7.3.4.2.1]	
Public Comment No. 260-NFPA 660-2024 [Section No. 8.4.5 [Excluding any Sub-Sections]]	
Public Comment No. 261-NFPA 660-2024 [Section No. 8.8.3.1]	
Public Comment No. 262-NFPA 660-2024 [Section No. A.8.8.3.1]	
Public Comment No. 263-NFPA 660-2024 [Section No. 8.9.3.4]	
Public Comment No. 264-NFPA 660-2024 [Section No. A.8.9.3.4]	
Public Comment No. 266-NFPA 660-2024 [Section No. 9.3.2.1]	
Public Comment No. 267-NFPA 660-2024 [Section No. 9.3.2.2 [Excluding any Sub-Sections]]	
Public Comment No. 268-NFPA 660-2024 [Section No. 9.3.3.1]	
Public Comment No. 269-NFPA 660-2024 [Section No. 9.3.3.2]	

Public Comment No. 270-NFPA 660-2024 [Section No. 9.3.5.1]
Public Comment No. 271-NFPA 660-2024 [Section No. 9.3.5.2.3]
Public Comment No. 272-NFPA 660-2024 [Section No. 9.3.5.3.1]
Public Comment No. 273-NFPA 660-2024 [Section No. 9.3.5.3.2]
Public Comment No. 274-NFPA 660-2024 [Section No. 9.3.5.3.3]
Public Comment No. 275-NFPA 660-2024 [Section No. 9.3.5.3.6]
Public Comment No. 277-NFPA 660-2024 [Section No. 9.3.5.4.2]
Public Comment No. 278-NFPA 660-2024 [Section No. 9.4.3.2.3]
Public Comment No. 279-NFPA 660-2024 [Section No. 9.4.3.3.5]
Public Comment No. 281-NFPA 660-2024 [Section No. 9.4.4.3]
Public Comment No. 282-NFPA 660-2024 [Section No. 9.4.4.6.1]
Public Comment No. 283-NFPA 660-2024 [Section No. 9.4.5.2]
Public Comment No. 286-NFPA 660-2024 [Section No. 9.4.6.3]
Public Comment No. 287-NFPA 660-2024 [Section No. 9.4.9.3.1]
Public Comment No. 289-NFPA 660-2024 [Section No. 9.4.9.3.2]
Public Comment No. 290-NFPA 660-2024 [Section No. 9.4.10]
Public Comment No. 291-NFPA 660-2024 [Section No. 9.4.12.2.4]
Public Comment No. 293-NFPA 660-2024 [Section No. 9.5.3.9]
Public Comment No. 294-NFPA 660-2024 [Section No. 9.6.3.2]
Public Comment No. 295-NFPA 660-2024 [Section No. 9.6.7.6]
Public Comment No. 296-NFPA 660-2024 [Section No. 9.6.11.3]
Public Comment No. 297-NFPA 660-2024 [Section No. 9.8.1]
Public Comment No. 299-NFPA 660-2024 [Section No. 9.8.2.1]
Public Comment No. 300-NFPA 660-2024 [Section No. A.9.8.2.1]
Public Comment No. 303-NFPA 660-2024 [Section No. 9.8.3.1]
Public Comment No. 304-NFPA 660-2024 [Section No. 9.8.3.3]
Public Comment No. 305-NFPA 660-2024 [Section No. 11.1.1]
Public Comment No. 306-NFPA 660-2024 [Section No. 11.7.3.1.2]
Public Comment No. 307-NFPA 660-2024 [Section No. 11.8.12.1.2]
Public Comment No. 308-NFPA 660-2024 [Section No. 11.9.3.5.3]
Public Comment No. 310-NFPA 660-2024 [Section No. 11.9.4.16.5]
Public Comment No. 311-NFPA 660-2024 [Section No. 11.9.4.17.1.4]
Public Comment No. 313-NFPA 660-2024 [Section No. 11.9.4.17.3.4]
Public Comment No. 315-NFPA 660-2024 [Section No. 11.9.4.17.4.4(F)]
Public Comment No. 318-NFPA 660-2024 [Section No. 11.9.4.19.1.2(C)]
Public Comment No. 319-NFPA 660-2024 [Section No. 11.9.4.20.1.2]
Public Comment No. 320-NFPA 660-2024 [Section No. 11.9.6.4.3]
Public Comment No. 321-NFPA 660-2024 [Section No. 11.9.8.1.1.1 [Excluding any Sub-Sections]]
Public Comment No. 323-NFPA 660-2024 [Section No. 12.1]
Public Comment No. 324-NFPA 660-2024 [Section No. 13.1]
Public Comment No. 325-NFPA 660-2024 [Section No. 14.1]
Public Comment No. 326-NFPA 660-2024 [Section No. 15.1]

Related Item

• Modified content to new section 3.3.38

Submitter Information Verification

Submitter Full Name: John LeBlanc
Organization: FM Global
Street Address:
City:
State:
Zip:
Submittal Date: Thu Jan 04 11:28:30 EST 2024
Committee: CMD-FUN

Committee Statement

Committee Action:	Rejected but held
Resolution:	This concept is being held for the next revision cycle because of its complexity, and it cannot be properly handled within the timeframe for processing the second draft.

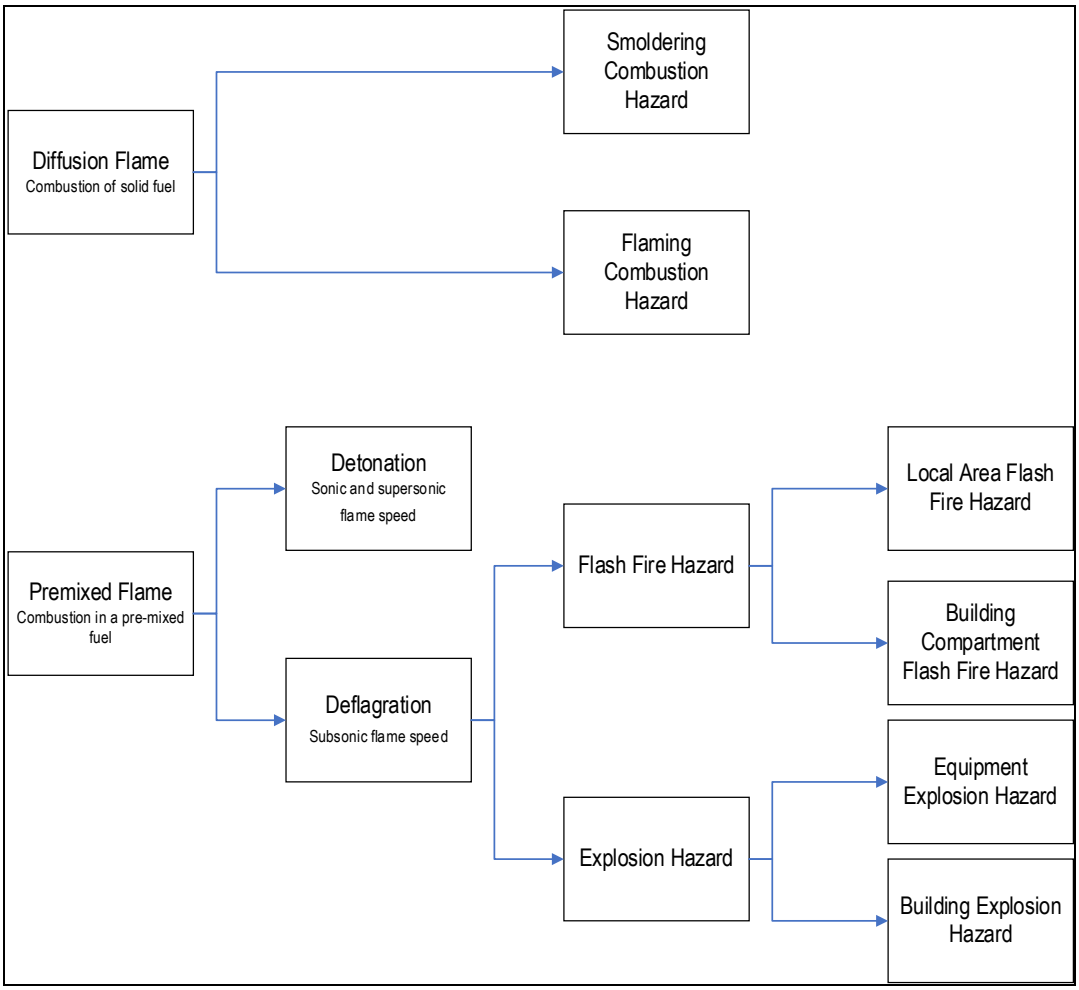


Figure A.3.3.38. Overview of Combustion Processes and Associated Hazards

Public Input No. 100-NFPA 660-2025 [Section No. 3.3.84]

3.3.84* Noncombustible Material.

~~A material that, in the form in which it is used and under the conditions anticipated, will not ignite, support combustion, burn, or release flammable vapors when subjected to fire or heat. (CMD-FUN~~ (See section 4.3)

Statement of Problem and Substantiation for Public Input

Note two important aspects:
1. The present definition of "noncombustible material" in NFPA 660 is severely flawed because it uses the phrase "under the conditions anticipated", which has the potential to refer to excessively mild conditions and is no longer considered an acceptable part of the definition of noncombustible material.
2. As the present annex note points out any material that "passes" ASTM E136 is considered a noncombustible material, even though it may exhibit some flaming, some mass loss and some temperature increase (all of which indicates that some combustion has occurred). This is because the acceptance criteria in ASTM E136 allow such small amount of combustion to occur, meaning that the existing phrase in the definition in NFPA 660 is not consistent with the annex note.
Furthermore, a material is considered noncombustible if it passed ASTM E136 and that is a requirement that should not be contained in NFPA definitions.
see PI 99 for further explanation

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 99-NFPA 660-2025 [New Section after 4.2.7]	
Public Input No. 101-NFPA 660-2025 [Section No. A.3.3.84]	
Public Input No. 99-NFPA 660-2025 [New Section after 4.2.7]	
Public Input No. 101-NFPA 660-2025 [Section No. A.3.3.84]	

Submitter Information Verification

Submitter Full Name: Marcelo Hirschler
Organization: GBH International
Street Address:
City:
State:
Zip:
Submittal Date: Tue Dec 23 17:18:11 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: It would not be appropriate to make this change to the definition of "noncombustible material" within the context of NFPA 660 because this term is used to describe particulates as well as construction materials, and the proposed new text would not be accurate for particulates. Specifically, the text proposed for 4.3.1.3 references steel and aluminum as examples of noncombustible materials, which is definitely not the case in the particulate form. A Committee Input is being created to clarify the differentiation between combustible particulates (process materials) and combustible materials of construction. "Under the conditions anticipated" is an important part of the definition in order to include important criteria such as particle size, morphology, moisture content, and oxidizing environment.

Public Input No. 69-NFPA 660-2025 [Section No. 4.2.4]

4.2.4 Compliance Options.

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

(1) The ~~prescriptive requirements~~ prescriptive requirements in Chapters 5 , 7 , ~~and~~ * ~~A hazard management program in conformance with the prescriptive requirements of Chapter 9 and the prescriptive hazard management requirements 8,9 and of the relevant industry- or commodity-specific chapter , or that meets the objectives of Chapter 4 and the relevant industry- or commodity-specific chapter through .~~

(2) Utilizing a performance-based design in accordance with ~~Chapter~~ 6 Chapter 6 in lieu of a prescriptive requirement in this standard.

Statement of Problem and Substantiation for Public Input

the original wording of this requirement was confusing to several people trying to review this standard. This PI is simply a rewording for clarity. it is not meant to change the intent of the orginal requirement.

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Dec 19 13:27:32 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: The revision proposed does make a technical change to the intent of this section. It appears to permit a performance-based approach to Chapters 5, 7, and 8 by putting Chapter 9 in the first paragraph. By eliminating "both" in the introductory statement, it would seem to permit a performance-based approach to the entire document, again eliminating the need to follow Chapters 5, 7, and 8, which is not the intent of the standard.

Public Input No. 173-NFPA 660-2026 [Sections 4.2.5, 4.2.6, 4.2.7]

Sections 4.2.5, 4.2.6, 4.2.7

4.2.5

~~Where a dust or particulate solid fire, flash fire, or explosion hazard~~

This standard shall be used to manage the hazards associated with fires or explosions from dusts, including combustible dusts, particulates or solids in the environments described in 4.2.5.1 through 4.2.5.3.

4.2.5.1

Where the hazards hazard exists within a process system~~, the hazards shall be managed in accordance with this standard~~ .

4.2.6

Where ~~a dust or particulate solid fire, flash fire, or explosion hazard exists within a~~ the hazards exist within a building or building compartment~~, the effects of the fire, flash fire, or explosion shall be managed in accordance with this standard~~ .

4.2.7

Where ~~an industry~~ the fires are addressed in an industry - or commodity-specific chapter~~ addresses hazards not associated with combustible dusts or particulate solids, those hazards shall be managed in accordance with this standard~~ .

Statement of Problem and Substantiation for Public Input

streamlining the requirements

Submitter Information Verification

Submitter Full Name: Marcelo Hirschler
Organization: GBH International
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jan 06 19:25:59 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: Changing these three statements into a list changes the intent of the sections. Specifically, 4.2.7 was meant to address requirements in the industry- and commodity-specific chapters such as hot oil systems that are not related to combustible dust hazards. Also, the rewording removes the hazard of flash fires, which is necessary for this standard to address.

Public Input No. 99-NFPA 660-2025 [New Section after 4.2.7]

4.3 Materials*

4.3.1 Noncombustible material (NFPA 5000-2027, section 7.1.4.1)

4.3.1.1 (NFPA 5000-2027, section 7.1.4.1.1)

A material that complies with any one of the following shall be considered a noncombustible material:

(1) The material, in the form in which it is used, and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat.

(2) The material is reported as passing ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C.*

(3) The material is reported as complying with the pass/fail criteria of ASTM E136 when tested in accordance with the test method and procedure in ASTM E2652, *Standard Test Method for Assessing Combustibility of Materials Using a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C.*

4.3.1.2 (NFPA 5000--2027, section 7.1.4.1.2)

Where the term *limited-combustible* is used in this code, it shall also include the term *noncombustible* .

4.3.1.3 (NFPA 5000--2027, section 7.1.4.1.3)

The following materials shall not be required to be tested to be acceptable as noncombustible materials, provided they do not contain any combustible components:

(1) Glass

(2) Steel

(3) 3xxx, 5xxx, and 6xxx series aluminum alloys

(4) Concrete

(5) Masonry

4.3.2 * Limited-Combustible Material.(NFPA 5000--2027, section 7.1.4.2)

A material shall be considered a limited-combustible material where one of the following is met:

(1)

(1)

The conditions of 4.3.2.1 and 4.3.2.2, and the conditions of either 4.3.2.3 or 4.3.2.4, shall be met.

(2)

(2)

The conditions of 4.3.2.5 shall be met.

4.3.2.1 (NFPA 5000--2027, section 7.1.4.2.1)

The material does not comply with the requirements for a noncombustible material in accordance with 4.3.1.

4.3.2.2 (NFPA 5000-2027, section 7.1.4.2.2)

The material, in the form in which it is used, exhibits a potential heat value not exceeding 3500 Btu/lb (8141 kJ/kg) when tested in accordance with NFPA 259 .

4.3.2.3 (NFPA 5000-2027, section 7.1.4.2.3)

The material shall have a structural base of noncombustible material with a surfacing not exceeding a thickness of 1⁄8 in. (3.2 mm) where the surfacing exhibits a flame spread index not greater than 50 when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials* , or UL 723, *Test for Surface Burning Characteristics of Building Materials* .

4.3.2.4 (NFPA 5000-2027, section 7.1.4.2.4)

The material shall be composed of materials that in the form and thickness used neither exhibit a flame spread index greater than 25 nor exhibit evidence of continued progressive combustion when tested in accordance with ASTM E84 or UL 723 and are of such composition that all surfaces that would be exposed by cutting through the material on any plane would neither exhibit a flame spread index greater than 25 nor exhibit evidence of continued progressive combustion when tested in accordance with ASTM E84 or UL 723.

4.3.2.5 (NFPA 5000-2027, section 7.1.4.2.5)

Materials shall be considered limited-combustible materials where tested in accordance with ASTM E2965, *Standard Test Method for Determination of Low Levels of Heat Release Rate for Materials and*

Products Using an Oxygen Consumption Calorimeter , at an incident heat flux of 75 kW/m ^{2} for a 20-minute exposure, and both the following conditions are met:

(1)

(1)

The peak heat release rate shall not exceed 150 kW/m ^{2} for longer than 10 seconds.

(2)

(2)

The total heat released shall not exceed 8 MJ/m ^{2} .

4.3.2.6 (NFPA 5000-2027, section 7.1.4.2.6)

Where the term *limited-combustible* is used in this *Code* , it shall also include the term *noncombustible* .

A.4.3 For the purposes of this standard, noncombustible construction and limited-combustible construction are both acceptable for use as noncombustible materials. In this document, the term *noncombustible material* is also used to refer to process materials that do not present a fire, flash fire, or explosion hazard as per Chapter 5.

A.4.3.4.2 (NFPA 5000-2027, section A.7.1.4.2)

Material subject to increase in combustibility or flame spread index beyond the limits herein established through the effects of age, moisture, or other atmospheric condition is considered combustible. *(See NFPA 259 and NFPA 220 .)*

Also: Please add also the relevant ASTM, UL and NFPA standards into section 2. The ASTM standards are: ASTM E84 (2025), ASTM E136 (2024c), ASTM E2652 (2022) and ASTM E2965 (20025)

Statement of Problem and Substantiation for Public Input

This PI recommends extracting the information about noncombustible materials and limited combustible materials from NFPA 5000-2027 edition. The associated PI recommends deleting the definition of noncombustible material from section 3 and referring to this section. This is what has been done in the majority of NFPA documents, including NFPA 1, NFPA 101, NFPA 5000, and many more. This provides uniformity among NFPA documents. The PI recommends retaining the critical part of the annex note to the definition of noncombustible material in the present edition.
Note two important aspects:
1. The present definition of "noncombustible material" in NFPA 660 is severely flawed because it uses the phrase "under the conditions anticipated", which has the potential to refer to excessively mild conditions and is no longer considered an acceptable part of the definition of noncombustible material.
2. As the present annex note points out any material that "passes" ASTM E136 is considered a noncombustible material, even though it may exhibit some flaming, some mass loss and some temperature increase (all of which indicates that some combustion has occurred). This is because the acceptance criteria in ASTM E136 allow such small amount of combustion to occur, meaning that the existing phrase in the definition in NFPA 660 is not consistent with the annex note.
Furthermore, a material is considered noncombustible if it passed ASTM E136 and that is a requirement that should not be contained in NFPA definitions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 100-NFPA 660-2025 [Section No. 3.3.84]	
Public Input No. 101-NFPA 660-2025 [Section No. A.3.3.84]	
Public Input No. 100-NFPA 660-2025 [Section No. 3.3.84]	
Public Input No. 101-NFPA 660-2025 [Section No. A.3.3.84]	

Submitter Information Verification

Submitter Full Name: Marcelo Hirschler
Organization: GBH International
Street Address:

City:
State:
Zip:
Submittal Date: Tue Dec 23 16:47:58 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: It would not be appropriate to make this change to the definition of "noncombustible material" within the context of NFPA 660 because this term is used to describe particulates as well as construction materials, and the proposed new text would not be accurate for particulates. Specifically, the text proposed for 4.3.1.3 references steel and aluminum as examples of noncombustible materials, which is definitely not the case in the particulate form. A Committee Input is being created to clarify the differentiation between combustible particulates (process materials) and combustible materials of construction. "Under the conditions anticipated" is an important part of the definition in order to include important criteria such as particle size, morphology, moisture content, and oxidizing environment.

Justification for changes to Enclosureless Dust Collector (EDC) requirement in NFPA 660

The hazards of fire, flash fire, and explosion are no different for wood or other nonmetallic solid particulates. Explosibility and ignitability data for wood, organic, and chemical dusts, demonstrate similar ranges in values in terms of K_{st}, P_{max}, Minimum Ignition Energy (MIE), Minimum Explosible Energy (MEC) and Minimum Ignition Temperature (MIT) cloud and layer values. Placement of requirements for EDCs in Chapter 9 and NFPA 660 is recommended. Requirements in Chapter 24 (Wood) and Chapter 25 (other combustible dusts and particulate solids not otherwise specified) should be removed from these chapters.

Analyzing the current requirements in Chapters 24 and Chapter 25 reveals the following:

- In **24.9.4.4.5** there are six (6) requirements for enclosureless dust collectors (a though g)
- In **25.9.4.4.4.5** There are 11 requirements for enclosureless dust collectors ((1) through (11))
- Three (3) of the requirements for EDCs are identical ([c] and (4)), ((f) and (7)) and ((g) and ((8))
- Fan motor requirements differ between Chapters, 24.9.4.4.5 (d) requires the fan motor to be of a totally enclosed, fan cooled design while 25.9.4.4.4.5.1(5) requires the fan motor to be suitable for Class II or Class III, Division 2, as appropriate, or Zone 22. The intent, in both cases, is believed to be to require selection of electrical equipment that is designed not to present an explosion hazard under upset conditions. In this case, the Chapter 24 requirement is too restrictive. The National Electrical Code NEC 70, Article 502.125 (B) (B) states,

  > *In Class II, Division 2 locations, motors, generators, and other rotating electrical equipment shall be totally enclosed nonventilated, totally enclosed pipe-ventilated, totally enclosed water-air-cooled, totally enclosed fan-cooled, or dust-ignitionproof, for which maximum full-load external temperature shall be in accordance with 500.8(D)(2) for normal operation when operating in free air (not dust blanketed) and shall have no external openings.*

  Thus, the Chapter 25 requirement for motors should be used as the new Universal requirement for EDCs.

1. Chapter 24 has no requirement for fan construction. Chapter 25 requires that, *"(10) the fan construction is spark resistant and meets the criteria in 9.4.5.4".* As written, this requirement contradicts the strict language in **9.4.5.4**. The requirement stated in 9.4.5.4 reads, *"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 Standard 99, Standards Handbook, or Type C spark-resistant construction protected with spark detection and extinguishment located downstream of the fan."* This implies that if the concentration of dust entering the blower is less than 10 percent of the MEC, then the AMD (fan in this case), need not be of spark resistant construction. Having performed hundreds of DHAs in industrial facilities all over the world, I can attest that there have been many instances where the dust loading in the fan is below this number. Nevertheless, it is prudent to require that the fan be of spark resistant construction. This is because, in many cases the solid loading in the duct

work entering the fan will be significant and a fire hazard will exist. Design of the fan to minimize the risk of producing an ignition source under a failure condition, is important.

Recommend that this requirement be re-written as follows: "*the fan shall be of Type A or Type B spark-resistant construction per AMCA Standard 99, Standards Handbook".*

- **Chapter 25 25.9.4.4.4.5.1(9)** requires that, "*the minimum ignition energy (MIE) of the collected material is greater than 500 mJ"*. No such required appears in the requirement for wood particulate (**24.9.4.4.5(7)).** The genesis of the Chapter 25 requirement is not known; however, this requirement is judged to be arbitrary and capricious. First and foremost, there is no such requirement for any of the previous commodity specific standards (61, 654, 655, 652) for fixed dry media dust collectors. In these types of dust collectors the dust is collected on the outside of the socks and periodically a blast of air is introduced into the inside of the socks to remove the dust. In situations where low MIE dusts are being collected, the standards require that all conductive components inside of the dust collector be bonded and grounded to prevent charge build-up which could lead to a spark discharge that would be incendive to low MIE dusts. Nonconductive filter media, can build up charge, leading to a brush discharge; however, it is well known that brush discharges are not an incendive ignition source even where low MIE dust clouds are formed. This would be the case, principally in an EDC's where the filter media would be either a nonconductive polyester or plastic sock or bag.

  If the genesis of this requirement was based on a pre-conceived notion that wood dust would not be expected to demonstrate MIEs less than 500 mJ, as an added attempt to achieve the same level of safety, when compared to the Chapter 24 requirement, there is an abundance of test data out in the public sector that refutes this position. Reported MIE data for wood products vary from as low as 10 mJ up to 1000 mJ. References include the following:

  - *Eckhoff, Rolf, "Dust Explosions in the Process Industries, third edition, Golf Professional Publishing, Table A.1, page 686.*
  - *BIA – Report 13/97 Combustion and Explosion Characteristics of Dusts, H. Beck, N. Glienke, C. MöhlrnannHVBG, Berufsgenossenschaftliches Institut fürArbeitssicherheit - BIA (Professional Association'sOccupational Safeiy Institute)Hauph/erband der gewerblichen Berufsgenossenschaften- HVBG (Federation of the Statutory Acident Insurance Institutions of the Industrial Sector),- November 1997.*

Recommended Changes to NFPA 660 for Enclosureless Dust Collectors

- **Remove requirements for Enclosureless dust collectors from Chapter 24 and 25.**

- **Provide a universal set of requirements in Chapter 9.**
- **Consolidate/modify the requirement to reflect the justification provided in this document.**

Recommended requirements to be established for enclosureless dust collectors in new Section in Chapter 9.

Modify Section 9.4.4.5 AMS Locations to add:

9.4.4.5.2 The requirement of 9.4.4.5.1 shall not apply to the following:

(1) AMSs that are protected in accordance with 9.8.2

(2) AMSs that are allowed by an industry- or commodity-specific chapter

(3) Enclosureless AMSs meeting all of the following criteria:

(a) The AMS is not used to vent or serve metal grinders, hot work processes, or machinery that can produce sparks.

(b) The AMS is not used to vent or serve sanders, molders, or abrasive planers, having mechanical feed through the machine.

(c) Each collector system has a maximum air flow–handling capacity of 5000 cfm (2.4 m^3/sec).

(d) The fan motor is suitable for Class II or Class III, Division 2, as appropriate, or Zone 22.

(e) The collected dust is removed daily or at a frequency sufficient to ensure efficient operation and to limit the collected dust to less than 22 lb (10 kg).

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

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

(h) The fan shall be of Type A or Type B spark-resistant construction per AMCA Standard 99, Standards Handbook".

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

~~**9.4.4.5.4 Enclosureless AMS shall not be permitted to be located indoors unless specifically allowed by an industry- or commodity-specific NFPA chapter.**~~

Public Input No. 52-NFPA 660-2025 [New Section after 5.3.1.2.1]

5.3.1.2.1.1

The determination of self-heating shall be permitted to be based upon historical facility data or published data that are deemed to be representative of current materials and process conditions.

Statement of Problem and Substantiation for Public Input

this statement is added for clarity and to align with similar wording in determination of combustibility section - so users know they do not need to send samples for testing for the products they already have experience, knowledge, and understanding - like agricultural commodititesl.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 56-NFPA 660-2025 [New Section after 21.5]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Dec 19 08:14:09 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: This is already allowed by the text in 5.3.1.2.1, so an additional statement like that in 5.2.2 is not necessary.

Public Input No. 53-NFPA 660-2025 [New Section after 5.3.2.2.1]

5.3.2.2.1.1

The determination of thermal instability shall be permitted to be based upon historical facility data or published data that are deemed to be representative or current materials and process conditions.

Statement of Problem and Substantiation for Public Input

this statement was added for clarity and aligns with wording used in the determining combustibility section so users understand they do not need to send samples for analysis for products they know well and have experience handling, like agricultural commodities.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 57-NFPA 660-2025 [New Section after 21.5]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Dec 19 08:20:52 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: This is already allowed by the text in 5.3.2.2.1, so an additional statement like that in 5.2.2 is not necessary.

Public Input No. 54-NFPA 660-2025 [New Section after 5.3.3.2.1]

5.3.3.2.1.1

The determination of water reactivity shall be permitted to be based upon historical facility data or published data that are deemed to be representative of current materials and process conditions.

Statement of Problem and Substantiation for Public Input

This statement is added for clarity and is aligned with the language in the determination of combustibility section - so users know they don't have to send samples for testing for products that are well known and have experience in handling, like agricultural commodities.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 58-NFPA 660-2025 [New Section after 21.5]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Dec 19 08:26:09 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: This is already allowed by the text in 5.3.3.2.1, so an additional statement like that in 5.2.2 is not necessary.

Public Input No. 55-NFPA 660-2025 [New Section after 5.3.4.2.1]

5.3.4.2.1.1

The determination of chemical reactivity shall be permitted to be based upon historical facility data or published data that are deemed to be representative of current materials and process conditions.

Statement of Problem and Substantiation for Public Input

this statement is added for clarity and is in alignment to language used in the determining combustibility section - so users know they do not need to send samples for testing for materials that are well known and have experience handling , like agricultural commodities

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 59-NFPA 660-2025 [New Section after 21.5]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Dec 19 08:37:30 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: This is already allowed by the text in 5.3.4.2.1, so an additional statement like that in 5.2.2 is not necessary.

Public Input No. 5-NFPA 660-2025 [Section No. 5.4.3.1]

5.4.3.1

Where the explosibility is not known, determination of explosibility of dusts shall be determined according to one of the following tests:

(1) The “Go/No-Go” screening test methodology described in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*

(2) ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*

(3) An equivalent test methodology

Additional Proposed Changes

File Name	Description	Approved
Determination_of_Explosibility_of_Dusts_June_2025.pdf	Rational for making the change	

Statement of Problem and Substantiation for Public Input

The NFPA Standard for Combustible Dust (NFPA 660) allows for use of either the go/no go screening test methodology described in ASTM E 1226, Standard Test Method for Explosibility of Dust Clouds“ or ASTM 1515, “Standard Test Method for Minimum Explosible Concentration of Combustible Dusts” to determine if the dust/powder is explosible (Section 5.4.3).
ASTM E 1515 (Section 5.5) recommends use of either 2500 or 5000 J pyrotechnic ignitors ignition sources for measuring the MEC of dusts in 20-L chambers.
ASTM E-1226, as currently written (Section 5.4), allows for use of either a 5.0 kJ or 10.0 kJ igniters to conduct testing to evaluate deflagration parameters of dusts. Also in Section 13, Explosibility Screening test. Section 13.1.1 states, “conduct initial tests using a 5 kJ or greater ignition source”.
Based on the choice of test method and the variability of ignition sources allowed, it is possible to determine explosibility properties, based on igniter energy levels that could vary by a magnitude of four (4). This can lead to reporting conflicting results. For example, results of the MEC test may indicate that the sample has no MEC, suggesting the sample is nonexplosible, while Screening test results may be reported as “Go”, indicating that the dust is explosible.
The potential ramifications of this present a significant process safety issue.
Recommended Solution
Revise both documents to provide a clear indication of the igniter energy that should be used for determination of whether the sample is explosible. The value should be consistent between the Standard Test Methods. It is recommended that a 5.0 kJ igniter be used. This energy is acceptable for testing in both Standards.

Submitter Information Verification

Submitter Full Name: Steven Luzik
Organization: Stonehouse Process Safety
Street Address:
City:
State:
Zip:
Submittal Date: Sun Jun 15 09:47:04 EDT 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-12-NFPA 660-2026

Statement: NFPA 660 previously allowed for use of either the go/no go screening test methodology described in ASTM E 1226, "Standard Test Method for Explosibility of Dust Clouds" or ASTM E 1515, “Standard Test Method for Minimum Explosible Concentration of Combustible Dusts” to determine if the dust/powder is explosible (Section 5.4.3).

ASTM E 1515 (Section 5.5) recommends use of either 2500 or 5000 J pyrotechnic ignitors ignition sources for measuring the MEC of dusts in 20-L chambers.

ASTM E 1226, as currently written (Section 5.4), allows for use of either a 5.0 kJ or 10.0 kJ igniters to conduct testing to evaluate deflagration parameters of dusts. Also in Section 13, Explosibility Screening test, Section 13.1.1 states, “conduct initial tests using a 5 kJ or greater ignition source”.

Based on the choice of test method and the variability of ignition sources allowed, it is possible to determine explosibility properties, based on igniter energy levels that could vary by a magnitude of four (4). This can lead to reporting conflicting results. For example, results of the MEC test may indicate that the sample has no MEC, suggesting the sample is nonexplosible, while Screening test results may be reported as “Go”, indicating that the dust is explosible.

The potential ramifications of this present a significant process safety issue.

ASTM E1515 has been deleted because it can be considered an equivalent test method when performed with a 5 kJ igniter.

Determination of Explosibility Characteristics of Powders and Dusts

Testing Issues

June 20255

Steven J Luzik PE, CFEI, Senior Process Safety Specialist

Stonehouse Process Safety

Statement of the Problem



- NFPA 660 requires that testing be conducted to determine whether the dust/powder is explosible.

5.4.3 Determination of Explosibility.
5.4.3.1 Where the explosibility is not known, determination of explosibility of dusts shall be determined according to one of the following tests:
(1) The "Go/No-Go" screening test methodology described in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*
(2) ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*
(3) An equivalent test methodology

Statement of the Problem



- Using either ASTM E1515 (MEC) or ASTM E1226 (Section 13 Screening test) to determine if the sample is explosible can lead to inconsistent results, in cases where hard to ignite or low K_{st} dusts are being tested.
- In some cases, a positive K_{st} value will be reported, indicating an explosion hazard, while MEC values are reported to be disingenuously high or non determinant.
- The reason for this inconsistency is because ignitor energies inside of the 20-L chamber can vary by a factor of four (2.5/5.0 kJ (MEC) 5.0/10.0kJ Explosion Severity) and still be compliant with these Standards.

Examples of Testing Results where Inconsistent Results have been Obtained

[redacted] Sample		
Test Screening- Unit	**Results**	**Comments**
Minimum Explosible Concentration (MEC) g/m³	>2000	Dust cloud explosible at a concentration of greater than 2000g/m³
Minimum Ignition Energy (MIE) mJ	MIE > 1000	No Ignition observed at 1000mJ
Minimum Autoignition Temperature (cloud) (°C)	>700	No ignition observed at 700 °C.
Maximum explosion pressure (Pmax) bar	3.9	-
Explosion Severity (Kst) bar.m/s	29	St-1 Class

[redacted] Sample		
Test Screening- Unit	**Results**	**Comments**
Minimum Explosible Concentration (MEC) g/m³	MEC > 2000g/m³	Dust Cloud Explosible at a concentration greater than 2,000g/m³
Minimum Ignition Energy (MIE) mJ	MIE > 1000mJ	No ignition observed at 1000mJ
Layer Ignition Temperature (°C)	LIT > 450°C	No ignition observed at 450°C
Minimum Autoignition Temperature (cloud) (°C)	MIT > 700°C	No ignition observed at 700°C.
Self-Heating Temperature (Grewer) – Screening (°C)	N/A	No self-heating reaction observed
Maximum explosion pressure (Pmax) bar	3.5	-
Explosion Severity (Kst) bar.m/s	44	St-1 Class

[redacted] Sample		
Test Screening- Unit	**Results**	**Comments**
Minimum Explosible Concentration (MEC) g/m³	>2000	Dust Cloud not Explosible up to a concentration of 2000g/m³
Minimum Ignition Energy (MIE) mJ	>1000	No ignition observed at 1000mJ
Layer Ignition Temperature (°C)	400	Fully chars at 400°C
Minimum Autoignition Temperature (cloud) (°C)	500	Autoignition observed at 500 °C.
Maximum explosion pressure (Pmax) bar	3.9	-
Explosion Severity (Kst) bar.m/s	31	St-1 Class

[redacted] Sample		
Test Screening- Unit	**Results**	**Comments**
Minimum Explosible Concentration (MEC) g/m³	>2000	No Dust Cloud Explosion up to a concentration of at 2000g/m³
Minimum Ignition Energy (MIE) mJ	MIE > 1000	No ignition observed at 1000mJ
Layer Ignition Temperature (°C)	N/A*	Fully melts at 410°C
Maximum explosion pressure (Pmax) bar	1.2	-
Explosion Severity (Kst) bar.m/s	16	St-1 Class

ASTM E1515 Test protocols

3.1.3 *minimum explosible concentration (MEC), n*—the minimum concentration of a combustible dust cloud that is capable of propagating a deflagration through a well dispersed mixture of the dust and air under the specified conditions of test.

5.5 The recommended ignition source for measuring the MEC of dusts in 20-L chambers is a 2500 or 5000 J pyrotechnic ignitor.[3] Measuring the MEC at both ignition energies will provide information on the possible overdriving of the system.[4] To evaluate the effect of possible overdriving in a 20-L chamber, comparison tests may also be made in a larger chamber, such as a 1 m^3-chamber.

5.6 If a dust ignites with a 5000 J ignitor but not with a 2500 J ignitor in a 20-L chamber, this may be an overdriven system.[4] In this case, it is recommended that the dust be tested with a 10 000 J ignitor in a larger chamber, such as a 1 m^3-chamber,

12.6 The minimum explosible concentration (MEC) is defined as the lowest concentration for which PR ≥ 2.0. The MEC is usually rounded to the nearest 5 g/m^3 or 10 %, whichever is larger. For the example shown in Fig. 3, the MEC would be 120 g/m^3.

ASTM E1226 Test Protocols

3.2.9 *deflagration index, K_{St}*—maximum *dP/dt* normalized to a 1.0-m^3 volume. It is measured at the optimum dust concentration. K_{St} is defined in accordance with the following cubic relationship:

$$K_{St} = (dP/dt)_{max} V^{1/3} \quad (1)$$

where:

P = pressure, bar,
t = time, s,
V = volume, m^3, and
K_{St} = bar m/s.

3.2.10 *explosible*—a material with a Pressure Ratio equal or greater than 2.0 in any test when tested using the Explosibility or Go/No-go Screening Test described in Section 13.

5.4 For hard-to-ignite dusts with low K_{St}-values, a very strong ignitor may overdrive a 20-L chamber, as discussed in E1515 and Ref (1).[7] If a dust has measurable (nonzero) P_{max}- and K_{St}-values with a 5000 or 10 000-J ignitor but not with a 2500-J ignitor in a 20-L chamber, this may be an overdriven system. In this case, it is recommended that the dust be tested with a 10 000-J ignitor in a larger chamber such as a 1-m^3 chamber to determine if it is actually explosible.

13. Explosibility or Go/No-Go Screening Tests

13.1 The objective of the screening test is to determine if the submitted dust sample is explosible or not. The test does not provide dust deflagration properties such as P_{max} and K_{St}.

13.1.1 Conduct initial tests using a 5 kJ or greater ignition source.

NOTE 13—Using an ignition source of 10 kJ (two 5-kJ igniters) is recommended in order to minimize the possibility of a false negative. However, if the researcher has concerns that the test may have been overdriven in the 20 L vessel while using the 10 kJ ignition source, then conduct the screening test using a 5 kJ source, or see Section 5.4.

Consequences of Using different Ignition energies to determine these properties

- For some powders/dusts, particularly those that are difficult to ignite or slow burning, there is no reported MEC (suggesting the dust cannot deflagrate) while a positive result (dust presents a deflagration hazard) will be returned for K_{st}.
- Consultants performing DHAs, have used a performance-based approaches to demonstrate that an explosion hazard does not exist. The genesis for this approach is NFPA 69 Chapter 8 "Deflagration Prevention by Combustible Concentration Reduction" that allows for reduction of flammable atmospheres as a valid Basis of Safety, if flammable atmospheres can be maintained at or below 25% of the LFL (LEL, MEC for dusts), for all foreseeable variations in operating conditions and material loadings. Where continuously monitored and controlled with safety interlocks, the combustible concentration is permitted to be maintained at or below 60% of the LFL.

Recommendations

- Add wording NFPA 660 Section 5.4.3.1 to require use of a 5.0 kJ ignition energy to perform Explosibility Screening and MEC testing to determine explosibility of a sample.

Public Input No. 170-NFPA 660-2026 [Section No. 6.3.4]

6.3.4 Mitigation of Fire Spread, Explosions, or Releases of Hazardous Materials.

When limitation of fire spread , ~~flash fire, and explosion spread~~ explosions, or releases of hazardous materials is to be achieved, all of the following criteria shall be demonstrated:

(1) Adjacent combustibles shall not attain their ignition temperature.

(2) Building design and housekeeping shall prevent combustibles from accumulating exterior to the enclosed process system to a concentration that is capable of supporting propagation.

(3) Particulate processing systems shall prevent fire, flash fire, or explosion from propagating from one process system to an adjacent process system or to the building interior.

Statement of Problem and Substantiation for Public Input

The first sentence in this section should align with the title.

Submitter Information Verification

Submitter Full Name: Geoffrey Raifsnider
Organization: Global Finishing Solutions
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jan 06 15:47:02 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: FR-13-NFPA 660-2026
Statement: Aligning the text in this section with the title, and with section 4.2.3. Flash fires are referenced in list item (3) and should be referenced in the title and introductory statement.

Public Input No. 143-NFPA 660-2026 [Section No. 7.2.3.2]

7.2.3.2

The ~~results of the DHA shall be maintained for the life of the process.~~ facility shall maintain the results of the most recent two DHAs.

Statement of Problem and Substantiation for Public Input

The value of maintaining DHAs is to reference the past DHA to understand changes in the system and recommendation progress. Going back three or more DHAs is invaluable as the information will be obsolete. The current DHA is most relevant to be the minimum requirement, and could accept requiring the current and one past assessment documentation, or up to 10 years of DHAs.

Examples of other risk assessment studies and retention timeframes: NFPA 70E states arch flash studies and electrical safety audits require only the current assessment to be maintained.

The lifetime requirement may have come from benchmarking with OSHA for PHAs. OSHA PSM requires facilities to keep the current and previous PSM Audit, but requires keeping PHAs for the lifetime of the process. In the hundreds of PHAs completed at our company, there has not been a need/value to keep for lifetime. Further, feedback from PSM auditors and PHA facilitators proves that there is lack of a need to reference PRAs for a lifetime. This requirement is burdensome and should be adjusted for DHAs. Propose requiring to keep last 2 in alignment with PSM audits.

Submitter Information Verification

Submitter Full Name: Julia Wiggen
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jan 02 16:13:08 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: It is important to be able to look back at previous DHAs, regardless of the amount of time that has passed, to determine if the recommendations have been addressed, or if not, the justification for rejecting the recommendation. With substantial turnover at facilities, it is important to retain the documentation and history of a facility. Historical DHAs assist with determining the basis of safety for existing equipment.

Public Input No. 81-NFPA 660-2025 [New Section after 7.3.3.3]

7.3.3.3.1

In addition to the conditions described in 7.3.3.3, a part of the process shall be considered an explosion hazard if the dust in that part of the process is enclosed.

Statement of Problem and Substantiation for Public Input

this statement was added for clarity is describing the 5 elements needed for a dust explosion as per the dust explosion pentagon.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 80-NFPA 660-2025 [Section No. 7.3.3.3]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 22 16:16:47 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-15-NFPA 660-2026
Statement: This text was added for clarity to describe the 5 elements needed for a dust explosion as per the dust explosion pentagon.

Public Input No. 157-NFPA 660-2026 [Section No. 7.3.3.3]

7.3.3.3*

Each part of the process that could potentially contain all of the following conditions shall be considered a dust flash fire or explosion hazard and shall be documented as such:

(1) A combustible particulate solid of sufficiently small particle size and sufficient quantity

(2) Air or other oxidizing atmosphere

(3) A competent ignition source

(4) A credible suspension mechanism that creates a dust cloud above the MEC of the dust

Statement of Problem and Substantiation for Public Input

on bullet point 4, the condition is suspended dust is a quantity that is explosive. Having the suspension mechanism only does not necessarily result in an explosible dust cloud.

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jan 05 15:07:25 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: The proposed modification to list item (4) is already addressed by list item (1) which requires a sufficient quantity of the combustible particulate solid.

Public Input No. 80-NFPA 660-2025 [Section No. 7.3.3.3]

7.3.3.3*

Each part of the process that could potentially contain all of the following conditions shall be considered a dust flash fire ~~or explosion~~ hazard and shall be documented as such:

(1) A combustible particulate solid of sufficiently small particle size and sufficient quantity

(2) Air or other oxidizing atmosphere

(3) A competent ignition source

(4) A credible suspension mechanism that creates a dust cloud above the MEC of the dust.

Statement of Problem and Substantiation for Public Input

the section describes the conditions needed to have a flash fire. the statement of having a dust cloud above the MEC is also required. For an explosion hazard to exist, there also needs to be containment. this condition is added in a suggested new section in another PI. i feel these technical details are important for clarity as there are multiple mitigation requirements that state 'where a dust explosion hazard exists..... this section should be as technically accurate as possible as it defines 'when does a dust explosion hazard exist'.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 81-NFPA 660-2025 [New Section after 7.3.3.3]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 22 16:11:02 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: The proposed modification to list item (4) is already addressed by list item (1) which requires a sufficient quantity of the combustible particulate solid.

Public Input No. 79-NFPA 660-2025 [New Section after 7.3.4.3]

7.3.4.3.1

In addition to the conditions in 7.3.4.3, the building or compartment shall be considered an explosion hazard if the compartment is enclosed.

Statement of Problem and Substantiation for Public Input

for clarity, this statement is added because confinement or enclosure is needed to have an explosion hazard as per the dust explosion pentagon

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 78-NFPA 660-2025 [Section No. 7.3.4.3]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 22 15:10:55 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-17-NFPA 660-2026

Statement: 7.3.4.4 was added for clarity to describe the 5 elements needed for a dust explosion as per the dust explosion pentagon.

"sufficient quantity" of a combustible particulate solid is necessary for completeness.

In response to PI 78, the proposed modification to list item (4) is now addressed by list item (1) which requires a sufficient quantity of the combustible particulate solid.

Public Input No. 78-NFPA 660-2025 [Section No. 7.3.4.3]

7.3.4.3

Each building or building compartment that could potentially contain all of the following conditions shall be considered a dust flash fire ~~or explosion~~ hazard and shall be documented as such:

(1) A combustible particulate solid of sufficiently small particle size and sufficient quantity.

(2) Air or other oxidizing atmosphere

(3) A competent ignition source

(4) A credible suspension mechanism to create a dust cloud above the MEC of the dust.

Statement of Problem and Substantiation for Public Input

this requirement describes conditions for a flash fire. to have an explosion, confinement is also needed. this clarification is added in another PI.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 79-NFPA 660-2025 [New Section after 7.3.4.3]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 22 15:07:19 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-17-NFPA 660-2026

Statement: 7.3.4.4 was added for clarity to describe the 5 elements needed for a dust explosion as per the dust explosion pentagon.

"sufficient quantity" of a combustible particulate solid is necessary for completeness.

In response to PI 78, the proposed modification to list item (4) is now addressed by list item (1) which requires a sufficient quantity of the combustible particulate solid.

Public Input No. 35-NFPA 660-2025 [Section No. 8.4.2.2.1.6]

8.4.2.2.1.6

Portable vacuum cleaners shall not be used on processes generating hot embers or sparks unless fitted with a system designed to extinguish embers and sparks .

Statement of Problem and Substantiation for Public Input

Portable vacuum cleaners may be equipped with protective systems, such as spark traps or ember suppression devices, designed to extinguish or contain hot particles before they reach the collection chamber. Prohibiting the use of all portable vacuum cleaners in operations that generate hot embers or sparks unnecessarily restricts the use of units that are specifically designed for safe operation under such conditions.

Submitter Information Verification

Submitter Full Name: Stephane Briquet
Organization: Tiger Vac International Inc
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 08 10:41:50 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: Due to the fact that many different materials can be involved, it is not feasible at this time to allow this broad of a standard for dry portable vacuum cleaners. There was a question whether spark arresting can be defined adequately to allow listing. Without a listing standard from an NRTL, there is no way to ensure the safety of the proposed system. A task group will be created to review this language and potential listing standards that may address this technology.

Public Input No. 68-NFPA 660-2025 [Section No. 8.4.2.2.2]

8.4.2.2.2 Centralized Vacuum Cleaning Systems.

A centralized vacuum cleaning system ~~remotely installed beyond the hazardous (classified) location~~ , in conformance with Section 9.4, shall be permitted to be used for vacuuming in combustible dust hazardous (classified) locations and where flammable vapors or gases are present in combustible dust hazardous (classified) locations.

Statement of Problem and Substantiation for Public Input

Centralized vacuum cleaning systems are commonly installed in Class II, Group G, Div 2 classified areas in grain elevators, feed mills, and flour mills. This is acceptable when they are properly protected, similar to a dust collector installed in the same area classification.

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Dec 19 12:59:19 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-19-NFPA 660-2026
Statement: Centralized vacuum cleaning systems are commonly installed in Class II, Group G, Div 2 classified areas in grain elevators, feed mills, and flour mills. This is acceptable when they are properly protected, similar to a dust collector installed in the same area classification. Section 9.6.5 contains requirements for electrical installations in hazardous (classified) locations.

Public Input No. 70-NFPA 660-2025 [Section No. 8.7.2]

8.7.2*

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

(1) Fire and explosion protection and prevention equipment~~- in accordance with the applicable NFPA standards~~

(2) Dust control equipment

(3) Housekeeping equipment

(4)~~*~~ ~~Potential ignition sources~~

(5) ~~Electrical, process, and mechanical equipment~~

(6)~~*~~ ~~Instrumentation~~ * Safety devices , including process interlocks

(7) Lubrication of bearings

(8) * Tramp metal detection and removal devices

Statement of Problem and Substantiation for Public Input

These requirements are for inspectable and maintainable equipment that prevents, controls or mitigations a combustible dust hazard. It should be items identified in the DHA used as protection / prevention layers. It is suggested to remove 'potential ignition source' from the list for clarity as that isn't a maintainable piece of equipment. I understand the annex gives a list of potential causes of ignition sources, but what should be maintained is the devices installed to detect the applicable causes. A belt alignment sensor is a maintainable piece of equipment (a safety device) that detects a potential ignition source inside of piece of equipment (ie: a bucket elevator). An explosion vent is an inspectable piece of explosion protection equipment (ie: on a bucket elevator). Those are examples that would fall under this list. Item#6 'Instrumentation' was replaced with 'Safety devices' for clarity. 'Safety devices' is a specific subset of instrumented (e.g. temperature for ignition source control, speed sensors for slip detection, pressure for over pressure events, spark detector, etc) and non-instrumented (e.g. relief valve) equipment that should be on the list rather than the entire list of all instruments that include process control devices (e.g. tank levels, position sensors, load cells, air pressure, etc). Item #5 'electrical, process, and mechanical equipment' should be removed for clarity as that encompasses everything in the plant rather than focusing on the equipment that prevents, controls, mitigates combustible dust hazards. Lastly 'in accordance with applicable NFPA standards' was deleted as there is already language in 8.7.1 that covers that.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 71-NFPA 660-2025 [New Section after 21.8.7.1]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Dec 19 13:55:24 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: See First Revision 20 for changes to this list. The intent of 8.7.2 is to establish the requirements for an ITM program and detail some of the components of such a program. Electrical, process, and mechanical equipment are common ignition sources and sources of failure that can create hazardous process events. There are types of instrumentation in addition to safety devices that ensure integrity of the process. Basic process controls are the first layer of protection and must be maintained.

Public Input No. 87-NFPA 660-2025 [Section No. 8.8.3]

8.8.3

Refresher training shall be provided ~~at least every three years after initial training or as required by the applicable industry- or commodity-specific chapters of this standard, whichever is shorter~~ annually .

Statement of Problem and Substantiation for Public Input

Section 8.9.3.6 says “Contractors shall receive refresher training annually.” That confused me, since employee training in section 8.8.3 said refresher training was required every 3 years. I wasn’t sure why contractors should be trained more frequently than employees, so I looked up the OSHA requirement. OSHA standard 1910.272 (e) Training (standard for Grain Handling Facilities) says:

“The employer shall provide training to employees at least annually and when changes in job assignment will expose them to new hazards. Current employees, and new employees prior to starting work, shall be trained in at least the following:
1910.272(e)(1)(i)
General safety precautions associated with the facility, including recognition and preventive measures for the hazards related to dust accumulations and common ignition sources such as smoking; and,
1910.272(e)(1)(ii)
Specific procedures and safety practices applicable to their job tasks including but not limited to, cleaning procedures for grinding equipment, clearing procedures for choked legs, housekeeping procedures, hot work procedures, preventive maintenance procedures and lock-out/tag-out procedures.
1910.272(e)(2)
Employees assigned special tasks, such as bin entry and handling of flammable or toxic substances, shall be provided training to perform these tasks safely.
Note to paragraph (e)(2): Training for an employee who enters grain storage structures includes training about engulfment and mechanical hazards and how to avoid them.”

Submitter Information Verification

Submitter Full Name: Rachel Slobotski
Organization: Cargill
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 22 16:43:17 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-21-NFPA 660-2026
Statement: This section is being revised to align with some of the industry- and commodity- specific chapters and requirements for contractor training. Refresher training does not have to be as comprehensive as the original training.

Public Input No. 26-NFPA 660-2025 [Section No. 8.9.3.6]

8.9.3.6

Contractors shall receive refresher training pertaining to the specific owner/operator facility annually.

Statement of Problem and Substantiation for Public Input

this change would clarify where the training must come from and who the responsibility of that training lays with.

Submitter Information Verification

Submitter Full Name: Seth Ricker
Organization: FEC
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 15 14:22:33 EDT 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-22-NFPA 660-2026
Statement: This revision ensures that the other requirements in 8.9.3 are covered by the refresher training.

Public Input No. 88-NFPA 660-2025 [Section No. 8.12.1]

8.12.1*

The owner/operator shall perform an operational readiness ~~reviewbefore~~ review before the start-up of the following:

(1) New facilities

(2) Modified facilities when the modification is significant enough to require change in the process and technology information required by 8.13.1(5)

(3) Facilities that have been shut down for minor maintenance activities

(4) Facilities that are periodically shut down as part of normal operations

(5) * Facilities that have been shut down for extended periods of time

Statement of Problem and Substantiation for Public Input

Added a space between the words review and before.

Submitter Information Verification

Submitter Full Name: Rachel Slobotski
Organization: Cargill
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 22 16:45:46 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-23-NFPA 660-2026
Statement: Added a space between the words "review" and "before".

Public Input No. 82-NFPA 660-2025 [Section No. 9.4.1.1]

9.4.1.1*

Where used to handle combustible particulate solids, systems shall be designed ~~by and installed under the supervision of qualified~~ by qualified persons who are knowledgeable about these systems and their associated hazards.

Statement of Problem and Substantiation for Public Input

i suggest deleting the statement that dust collection system need to be installed under the supervision of a person with the same knowledge of the system as the designer of the systems. Contractors are supervised for following safety policies / procedures and installing equipment as per drawings provided. that supervisor may not know if the system is designed correctly. This requirement could incorrectly result in facilities having to contract out to engineering providers to act as supervisors during installation of these systems.

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 22 16:23:58 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: The definition of qualified person permits a facility employee to do this supervision, as long as they have the proper knowledge and skills. It is important to have supervision to ensure that the design intent has been achieved.

Public Input No. 67-NFPA 660-2025 [Section No. 9.4.2.3]

9.4.2.3

Openings provided specifically for inspection ~~or necessary~~ on necessary process intake or discharge shall be permitted, provided they too do not permit fugitive dust release.

Statement of Problem and Substantiation for Public Input

it appears that this was a typo and 'or' was inserted rather than 'on' .

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Dec 19 12:56:21 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-26-NFPA 660-2026
Statement: This revision clarifies the intent of the requirement with no technical change.

Public Input No. 19-NFPA 660-2025 [Section No. 9.4.4.5.2]

9.4.4.5.2

The requirement of 9.4.4.5.1 shall not apply to the following:

(1) AMSs that are protected in accordance with 9.8.2

(2) AMSs that are allowed by an industry- or commodity-specific chapter

(3) Enclosureless dust collectors meeting al of the following criteria:

(a) The AMS is not used to vent or serve metal grinders, hot work processes, or machinery that can produce sparks.

(b) The AMS is not used to vent or serve sanders, molders, or abrasive planers, having mechanical feed through the machine.

(c) Each collector system has a maximum air flow–handling capacity of 5000 cfm (2.4 m^3/sec).

(d) The fan motor is suitable for Class II or Class III, Division 2, as appropriate, or Zone 22.

(e) The collected dust is removed daily or at a frequency sufficient to ensure efficient operation and to limit the collected dust to less than 22 lb (10 kg).

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

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

(h) The fan shall be of Type A or Type B spark-resistant construction per AMCA Standard 99, Standards Handbook".

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

Additional Proposed Changes

File Name	Description	Approved
Public_Comment_Enclosureless_DCs_Justification_For_Changing_Current_Requirements.docx	Justification for changing requirements for EDCs	

Statement of Problem and Substantiation for Public Input

The hazards of fire, flash fire, and explosion are no different for wood or other nonmetallic solid particulates. Explosibility and ignitability data for wood, organic, and chemical dusts, demonstrate similar ranges in values in terms of Kst, Pmax, Minimum Ignition Energy (MIE), Minimum Explosible Energy (MEC) and Minimum Ignition Temperature (MIT) cloud and layer values. Placement of requirements for EDCs in Chapter 9 and NFPA 660 is recommended. Requirements in Chapter 24 (Wood) and Chapter 25 (other combustible dusts and particulate solids not otherwise specified) should be removed from these chapters.

Submitter Information Verification

Submitter Full Name: Steven Luzik
Organization: Stonehouse Process Safety
Street Address:
City:
State:

Zip:

Submittal Date: Fri Jun 20 09:21:50 EDT 2025

Committee: CMD-FUN

Committee Statement

Resolution: Enclosureless dust collectors are not permitted by the agricultural dust chapter, sulfur dust chapter, or the metal dust chapter so it is not appropriate to provide a fundamental allowance for these. It is up to the individual industry- and commodity-specific technical committees to determine whether they should be allowed for their industry.

Public Input No. 51-NFPA 660-2025 [Section No. 9.4.4.5.3]

9.4.4.5.3

Wet air-material separators shall be permitted to be located inside when all of the following criteria are met:

(1) A means is provided to prevent startup or continued operation if the flow rate of the scrubbing medium is less than the designed minimum flow rate.

(2) The scrubbing medium ~~is not an ignitible (flammable or combustible) liquid~~ shall be limited to nonaqueous Class IIIB (flash point ≥ 200°F (93°C)] or noncombustible liquids .

(3) The separator is designed to prevent the formation of a combustible dust cloud within the air-material separator.

(4) The design of the separator addresses any reaction between the separated material and the scrubbing medium.

Statement of Problem and Substantiation for Public Input

Inconsistency between Ch. 9 and Ch. 22 requirements for scrubbing medium in wet AMS.

Submitter Information Verification

Submitter Full Name: Laura Jacobsen
Organization: The Boeing Company
Street Address:
City:
State:
Zip:
Submittal Date: Wed Dec 17 17:24:10 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: The conflicts section in Chapter 1 allows differences between the fundamentals chapter and the metal dust chapter. There are several other requirements in 22.9.4.4.3.12 that are not reflected here and need to be followed for wet scrubbers using a Class IIIB liquid (for example, mineral oil).

Public Input No. 20-NFPA 660-2025 [Section No. 9.4.4.5.4]

~~**9.4.4.5.4** –~~

~~Enclosureless AMS shall not be permitted to be located indoors unless specifically allowed by an industry- or commodity-specific NFPA chapter.~~

Additional Proposed Changes

File Name	Description	Approved
Public_Comment_Enclosureless_DCs_Justification_For_Changing_Current_Requirements.docx	Justification for changing requirements for EDCs	

Statement of Problem and Substantiation for Public Input

The hazards of fire, flash fire, and explosion are no different for wood or other nonmetallic solid particulates. Explosibility and ignitability data for wood, organic, and chemical dusts, demonstrate similar ranges in values in terms of Kst, Pmax, Minimum Ignition Energy (MIE), Minimum Explosible Energy (MEC) and Minimum Ignition Temperature (MIT) cloud and layer values. Placement of requirements for EDCs in Chapter 9 and NFPA 660 is recommended. Requirements in Chapter 24 (Wood) and Chapter 25 (other combustible dusts and particulate solids not otherwise specified) should be removed from these chapters.

Submitter Information Verification

Submitter Full Name: Steven Luzik
Organization: Stonehouse Process Safety
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jun 20 09:27:12 EDT 2025
Committee: CMD-FUN

Committee Statement

Resolution: Enclosureless dust collectors are not permitted by the agricultural dust chapter, sulfur dust chapter, or the metal dust chapter so it is not appropriate to provide a fundamental allowance for these. It is up to the individual industry- and commodity-specific technical committees to determine whether they should be allowed for their industry.

Justification for changes to Enclosureless Dust Collector (EDC) requirement in NFPA 660

The hazards of fire, flash fire, and explosion are no different for wood or other nonmetallic solid particulates. Explosibility and ignitability data for wood, organic, and chemical dusts, demonstrate similar ranges in values in terms of K_{st}, P_{max}, Minimum Ignition Energy (MIE), Minimum Explosible Energy (MEC) and Minimum Ignition Temperature (MIT) cloud and layer values. Placement of requirements for EDCs in Chapter 9 and NFPA 660 is recommended. Requirements in Chapter 24 (Wood) and Chapter 25 (other combustible dusts and particulate solids not otherwise specified) should be removed from these chapters.

Analyzing the current requirements in Chapters 24 and Chapter 25 reveals the following:

- In **24.9.4.4.5** there are six (6) requirements for enclosureless dust collectors (a though g)
- In **25.9.4.4.4.5** There are 11 requirements for enclosureless dust collectors ((1) through (11))
- Three (3) of the requirements for EDCs are identical ([c] and (4)), ((f) and (7)) and ((g) and ((8))
- Fan motor requirements differ between Chapters, 24.9.4.4.5 (d) requires the fan motor to be of a totally enclosed, fan cooled design while 25.9.4.4.4.5.1(5) requires the fan motor to be suitable for Class II or Class III, Division 2, as appropriate, or Zone 22. The intent, in both cases, is believed to be to require selection of electrical equipment that is designed not to present an explosion hazard under upset conditions. In this case, the Chapter 24 requirement is too restrictive. The National Electrical Code NEC 70, Article 502.125 (B) (B) states,

  > *In Class II, Division 2 locations, motors, generators, and other rotating electrical equipment shall be totally enclosed nonventilated, totally enclosed pipe-ventilated, totally enclosed water-air-cooled, totally enclosed fan-cooled, or dust-ignitionproof, for which maximum full-load external temperature shall be in accordance with 500.8(D)(2) for normal operation when operating in free air (not dust blanketed) and shall have no external openings.*

  Thus, the Chapter 25 requirement for motors should be used as the new Universal requirement for EDCs.

1. Chapter 24 has no requirement for fan construction. Chapter 25 requires that, *"(10) the fan construction is spark resistant and meets the criteria in 9.4.5.4".* As written, this requirement contradicts the strict language in **9.4.5.4**. The requirement stated in 9.4.5.4 reads, *"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 Standard 99, Standards Handbook, or Type C spark-resistant construction protected with spark detection and extinguishment located downstream of the fan."* This implies that if the concentration of dust entering the blower is less than 10 percent of the MEC, then the AMD (fan in this case), need not be of spark resistant construction. Having performed hundreds of DHAs in industrial facilities all over the world, I can attest that there have been many instances where the dust loading in the fan is below this number. Nevertheless, it is prudent to require that the fan be of spark resistant construction. This is because, in many cases the solid loading in the duct

work entering the fan will be significant and a fire hazard will exist. Design of the fan to minimize the risk of producing an ignition source under a failure condition, is important.

Recommend that this requirement be re-written as follows: "*the fan shall be of Type A or Type B spark-resistant construction per AMCA Standard 99, Standards Handbook".*

- **Chapter 25 25.9.4.4.4.5.1(9)** requires that, "*the minimum ignition energy (MIE) of the collected material is greater than 500 mJ"*. No such required appears in the requirement for wood particulate (**24.9.4.4.5(7)).** The genesis of the Chapter 25 requirement is not known; however, this requirement is judged to be arbitrary and capricious. First and foremost, there is no such requirement for any of the previous commodity specific standards (61, 654, 655, 652) for fixed dry media dust collectors. In these types of dust collectors the dust is collected on the outside of the socks and periodically a blast of air is introduced into the inside of the socks to remove the dust. In situations where low MIE dusts are being collected, the standards require that all conductive components inside of the dust collector be bonded and grounded to prevent charge build-up which could lead to a spark discharge that would be incendive to low MIE dusts. Nonconductive filter media, can build up charge, leading to a brush discharge; however, it is well known that brush discharges are not an incendive ignition source even where low MIE dust clouds are formed. This would be the case, principally in an EDC's where the filter media would be either a nonconductive polyester or plastic sock or bag.

  If the genesis of this requirement was based on a pre-conceived notion that wood dust would not be expected to demonstrate MIEs less than 500 mJ, as an added attempt to achieve the same level of safety, when compared to the Chapter 24 requirement, there is an abundance of test data out in the public sector that refutes this position. Reported MIE data for wood products vary from as low as 10 mJ up to 1000 mJ. References include the following:

  - *Eckhoff, Rolf, "Dust Explosions in the Process Industries, third edition, Golf Professional Publishing, Table A.1, page 686.*
  - *BIA – Report 13/97 Combustion and Explosion Characteristics of Dusts, H. Beck, N. Glienke, C. MöhlrnannHVBG, Berufsgenossenschaftliches Institut fürArbeitssicherheit - BIA (Professional Association'sOccupational Safeiy Institute)Hauph/erband der gewerblichen Berufsgenossenschaften- HVBG (Federation of the Statutory Acident Insurance Institutions of the Industrial Sector),- November 1997.*

Recommended Changes to NFPA 660 for Enclosureless Dust Collectors

- **Remove requirements for Enclosureless dust collectors from Chapter 24 and 25.**

- **Provide a universal set of requirements in Chapter 9.**
- **Consolidate/modify the requirement to reflect the justification provided in this document.**

Recommended requirements to be established for enclosureless dust collectors in new Section in Chapter 9.

Modify Section 9.4.4.5 AMS Locations to add:

9.4.4.5.2 The requirement of 9.4.4.5.1 shall not apply to the following:

(1) AMSs that are protected in accordance with 9.8.2

(2) AMSs that are allowed by an industry- or commodity-specific chapter

(3) Enclosureless AMSs meeting all of the following criteria:

(a) The AMS is not used to vent or serve metal grinders, hot work processes, or machinery that can produce sparks.

(b) The AMS is not used to vent or serve sanders, molders, or abrasive planers, having mechanical feed through the machine.

(c) Each collector system has a maximum air flow–handling capacity of 5000 cfm (2.4 m^3/sec).

(d) The fan motor is suitable for Class II or Class III, Division 2, as appropriate, or Zone 22.

(e) The collected dust is removed daily or at a frequency sufficient to ensure efficient operation and to limit the collected dust to less than 22 lb (10 kg).

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

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

(h) The fan shall be of Type A or Type B spark-resistant construction per AMCA Standard 99, Standards Handbook".

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

~~**9.4.4.5.4 Enclosureless AMS shall not be permitted to be located indoors unless specifically allowed by an industry- or commodity-specific NFPA chapter.**~~

Public Input No. 21-NFPA 660-2025 [Section No. 9.4.5]

9.4.5 Air-Moving Devices (Fans and Blowers).

9.4.5.1–

~~AMDs~~

AMDs shall conform to the requirements of NFPA 91, except as amended by the requirements of this chapter.

9.4.5.2*–

~~Where~~

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

9.4.5.3*–

~~The~~

The requirement of 9.4.5.2 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 9.8.2.2(1) , 9.8.2.2(5) , 9.8.2.2(6) , or 9.8.3 .

~~Where~~
9.4.5.4

*–
The requirement of 9.4.5.2 shall not apply to systems where both of the following requirements are met:

(1) The system is designed to operate at a combustible particulate solids concentration less than 25 of percent of the MEC of the dust.

(2) Hybrid mixtures are not present.

9.4.5.5 Where an AMD is located in the dirty air stream and the dust/air stream concentration is higher than*

~~10 percent~~
25 percent of the MEC, fans and blowers shall be of Type A or Type B spark-resistant construction per AMCA Standard 99,

~~Standards~~
Standards Handbook , or Type C spark-resistant construction protected with spark detection and extinguishment located downstream of the fan

9 . 4.5.6 *Where a fire hazard exists and where combustible particulate solids pass through an AMD, provisions shall be made to prevent ignited material from entering processes downstream, in accordance with Section 9.9.*

Additional Proposed Changes

File Name	Description	Approved
Justification_for_changing_Section_on_Solids_passing_through_an_AMD.docx	Justification for Changing Sections on Solids passing through an AMD	

Statement of Problem and Substantiation for Public Input

As currently written, NFPA 660 Section 9.4.5.4 requires that, “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 Standard 99, Standards Handbook, or Type C spark-resistant construction protected with spark detection and extinguishment located downstream of the fan.”
It is universally accepted that a dust cloud, at a concentration below its lower flammable limit (LFL) or Minimum Explosible Concentration (MEC), cannot ignite and propagate flame. The current threshold concentration limit is unreasonably restrictive and is not aligned with NFPA 69 Standard for Explosion Prevention Systems. Chapter 8 of NFPA 69 provides a strategy for providing deflagration prevention by combustible concentration reduction. In this regard the Standard states the following:
The combustible concentration shall be maintained at or below 25 percent of the LFL for all foreseeable variations in operating conditions and material loadings, unless the following conditions apply:
(1) Where continuously monitored and controlled with safety interlocks, the combustible concentration shall be permitted to be maintained at or below 60 percent of the LFL.
(2) Aluminum powder production systems designed and operated in accordance with NFPA 484 shall be permitted to be maintained at or below 50 percent of the LFL.
Furthermore, in situations where solid particulates pass through an air moving device (AMD), a fire hazard will exist. The risk of a fire will increase as the amount of particulate in the ductwork increases. It is prudent to require that provisions be made to prevent ignited material from entering processes downstream, in accordance with Section 9.9.
Finally, a similar requirement in situations where solids pass through an AMD appears in Chapter 25 (Combustible Dusts and Particulate Solids Not Otherwise Specified Specified). This requirement though, recognizes the important potential of a fire hazard. In the interest of consolidation and making the standard easier to navigate, changes are recommended.

Submitter Information Verification

Submitter Full Name: Steven Luzik
Organization: Stonehouse Process Safety
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jun 23 11:50:03 EDT 2025
Committee: CMD-FUN

Committee Statement

Resolution: CI-37-NFPA 660-2026
Statement: The committee needs more time to review the changes to this section and the thresholds of 10 percent vs 25 percent of the MEC. A task group has been formed to review this CI and PI 21.

Justification for revising the Requirement where Solids Pass Through an AMD

As currently written, NFPA 660 **Section 9.4.5.4** requires that, *"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 Standard 99, Standards Handbook, or Type C spark-resistant construction protected with spark detection and extinguishment located downstream of the fan."*

The requirement and the justification for the requirement can be found in the 2013 revision of NFPA 654 (where the standard was set) are as follows:

7.12.2.2* *The requirement of 7.12.2.1 shall not apply to systems designed to operate at a combustible particulate solids concentration or hybrid mixture concentration of less than 10 percent of the MEC or for a hybrid mixture, the lower of 10 percent of the MEC of the dust, or 10 percent of the LFL of the vapor.*

**** A.7.12.2.2*** *Some systems are designed to operate at solids concentrations that pose no fire or deflagration risk. Such systems include nuisance dust exhaust systems and the downstream side of the last air-material separator in the pneumatic conveying system. A threshold concentration limit of 10 percent of the MEC has been set to discriminate between such systems and other systems designed to operate at a significant combustible solid loading. This limit ensures that normal variations in processing conditions do not result in the combustible particulate or hybrid mixture concentration approaching the MEC.*

Issue with the Current Requirement

It is universally accepted that a dust cloud, at a concentration below its lower flammable limit (LFL) or Minimum Explosible Concentration (MEC), cannot ignite and propagate flame. The current threshold concentration limit is unreasonably restrictive and is not aligned with *NFPA 69 Standard for Explosion Prevention Systems.*

Chapter 8 of NFPA 69 provides a strategy for providing deflagration prevention by combustible concentration reduction. In this regard the Standard states the following:

8.1* Application*. The technique for combustible concentration reduction shall be permitted to be considered where a mixture of a combustible material and an oxidant is confined to an enclosure and where the concentration of the combustible can be maintained below the lower flammable limit (LFL).*

8.3 Design and Operating Requirements.

8.3.1* Combustible Concentration Limit*.*

The combustible concentration shall be maintained at or below 25 percent of the LFL for all foreseeable variations in operating conditions and material loadings, unless the following conditions apply:

(1) Where continuously monitored and controlled with safety interlocks, the combustible concentration shall be permitted to be maintained at or below 60 percent of the LFL.

(2) Aluminum powder production systems designed and operated in accordance with NFPA 484 shall be permitted to be maintained at or below 50 percent of the LFL.

Furthermore, in situations where solid particulates pass through an air moving device (AMD), a fire hazard will exist. The risk of a fire will increase as the amount of particulate in the ductwork increases. It is prudent to require that provisions be made to prevent ignited material from entering processes downstream, in accordance with **Section 9.9**.

Finally, a similar requirement in situations where solids pass through an AMD appears in Chapter 25 (Combustible Dusts and Particulate Solids Not Otherwise Specified Specified). This requirement though, recognizes the important potential of a fire hazard. In the interest of consolidation and making the standard easier to navigate, it is recommended that the following changes be made:

Change the requirements in Section 9.4.5.12 read as follows:

9.4.5 *Air-Moving Devices (Fans and Blowers).*

9.4.5.1 *AMDs shall conform to the requirements of NFPA 91, except as amended by the requirements of this chapter.*

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

9.4.5.3 The requirement of 9.4.5.2 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 9.8.2.2(1), 9.8.2.2(5), 9.8.2.2(6), or 9.8.3.*

9.4.5.4 *The requirement of 9.4.5.2 shall not apply to systems where both of the following requirements are met:*

(1) The system is designed to operate at a combustible particulate solids concentration less than 25 of percent of the MEC of the dust.

(2) Hybrid mixtures are not present.

9.4.5.5 Where an AMD is located in the dirty air stream and the dust/air stream concentration is higher than 25 percent of the MEC, fans and blowers shall be of Type A or Type B spark-resistant construction per AMCA Standard 99, Standards Handbook, or Type C spark-resistant construction protected with spark detection and extinguishment located downstream of the fan*

9.4.5.6 *Where a fire hazard exists and where combustible particulate solids pass through an AMD, provisions shall be made to prevent ignited material from entering processes downstream, in accordance with Section 9.9.*

***Remove Section* 25.9.4.5**

Public Input No. 66-NFPA 660-2025 [Section No. 9.4.9.5]

9.4.9.5 Access Doors and 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.~~

Statement of Problem and Substantiation for Public Input

Since this requirement references AMS rather than bulk storage enclosures, it appears to have been a copy / paste error. I suggest deleting the requirement as this standard should not have a requirement on the structural design of a door in a bulk storage vessel. Those requirements are covered in bin design standards.

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Dec 19 12:44:35 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-28-NFPA 660-2026
Statement: This requirement is in the bulk storage enclosure section and should not have referenced AMS. This revision also makes it clear that the access door can be designed to be stronger than the enclosure per NFPA 68.

Public Input No. 84-NFPA 660-2025 [Section No. 9.4.12.2.4]

~~9.4.12.2.4~~ ~~*~~ –

~~Pressure relief devices shall not be vented to an area where a dust or particulate solid fire, flash fire, or explosion hazard exists in accordance with 7.3.4 .~~

Statement of Problem and Substantiation for Public Input

I suggest to delete this requirement as requiring all pressure relief valves to be piped to a clean room is overly cautious. Pressure relief valves on positive displacement blowers are commonly near the blower and can be (are often times) located in a processing area where some dust could be present. Any dust that could be put in suspension will be small and for a very short duration. This is described in the area classification definitions (Zone 21, Zone 22, Class II Div 2) where dust may be in suspension, but for a short period of time.

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 22 16:32:07 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: This requirement does not specify that the pressure relief valve must be piped to a clean room, just to a cleaner portion or elevation of the space that does not contain a dust hazard. It is necessary to prevent suspending a dust cloud from accumulated layers. It cannot be safely assumed that any dust put into suspension will be small and for a short duration.

Public Input No. 75-NFPA 660-2025 [Section No. 9.4.14]

9.4.14 Bucket Elevators.

~~For requirements on bucket elevators, see industry- or commodity-specific chapters~~ No bearings shall be located in the bucket elevator casing .

Statement of Problem and Substantiation for Public Input

In consolidating the fundamentals document (NFPA 652) and the industry/commodity specific standards (NFPA 61, 484, 654 and 664) into the new NFPA 660, it appears that a requirement prohibiting bearings from being located in the bucket elevator casing was omitted. The proposed requirement shown in this PI is taken from the prior edition of NFPA 652, paragraph 9.3.14.4.3. An identical requirement was contained in the prior editions of NFPA 484 (see 9.3.14.4.3 shown as extracted from 652) and NFPA 654 (see 9.3.10.6). The proposed edit to NFPA 660, Chapter 9 seeks to capture this requirement that previously existed, but appears to have been omitted in the consolidation effort, even though no technical changes were intended in that effort. Current paragraph 9.4.14 of NFPA 660 directs the user to the industry/commodity specific chapters (21, 22, 23, 24, or 25) for requirements applying to protection of bucket elevators. But the protection against bearings being located in bucket elevator casings is not included in any of those chapters. Unless, the committee has a specific technical reason for excluding this prior requirement from the new consolidated standard, NFPA 660, I believe the proposed action should be accepted as a first revision.

Submitter Information Verification

Submitter Full Name: Guy Colonna
Organization: FSL Consulting LLC
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 22 12:02:38 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-29-NFPA 660-2026
Statement: This requirement was previously in NFPA 652, 654, and 484 and is fundamental to all types of combustible dusts. Locating bearings in bucket elevator casings is a combustible dust hazard and should not be permitted.

Public Input No. 64-NFPA 660-2025 [Section No. 9.4.17.1.8]

9.4.17.1.8*

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

- ~~Heated air supply to the drying chamber~~

~~Airstream at the discharge of the~~ (1) Temperature of the hot air drying chamber

Statement of Problem and Substantiation for Public Input

Bullet point (1) is corrected to monitor the hot air chamber itself and not the duct work of hot air feeding the hot air chamber. This device is used to prevent overheating in the dryer that can cause dryer smolders.

Bullet point (2) is a good practice when used as an array of sensors to use an an early detection method to detect if there is a choked column or a section of the dryer (noting an abnormal temperature differential among the sensor array) but is not a fundamental requirement for all dryers. It is suggested this bullet point be moved to the Annex.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 65-NFPA 660-2025 [Section No. A.9.4.17.1.8]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Dec 19 12:37:10 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: CI-30-NFPA 660-2026
Statement: The committee agrees that revisions are needed based on Public Input 64 and 65, but additional time is needed to develop the text, specifically for non-heated air dryers. A task group has been formed.

Public Input No. 167-NFPA 660-2026 [Section No. 9.6.6.1.1]

9.6.6.1.1

Particulate handling equipment shall be conductive unless the provisions of 9.6.6.1.2, 9.6.6.1.4.4, 9.6.6.3.2, 9.6.6.4, 9.6.6.5.2, or 9.6.8.2 are applicable.

Statement of Problem and Substantiation for Public Input

Additional exception provisions should be added for nonconductive non-fixed equipment that have already been identified later in this chapter as being acceptable such as flexible connectors meeting the provisions of 9.6.6.1.4.4, personnel (although not technically "equipment") meeting the provisions of 9.6.6.3.2, type A FIBCs meeting the provisions of section 9.6.6.4, non-conductive RIBCs meeting the provisions of 9.6.6.5.2, and non-listed industrial trucks meeting the provisions of 9.6.8.2

Submitter Information Verification

Submitter Full Name: Eric Winter
Organization: Corteva Agriscience
Affiliation: NFPA 77 TG#8
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jan 06 15:00:37 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: FR-38-NFPA 660-2026

Statement: Note: There is a separate revision (FR 39) that deletes 9.6.6.1.4.1 and A.9.6.6.1.4.1. This ballot item, FR 38, makes the other changes to 9.6.6.

Changes were made to section 9.6.6 and its annex to address the use of nonconductive equipment.

Section 9.6.6.1 was modified to specifically reference section 9.6.6.1.4 regarding flexible connectors where applicable, in response to PI 167. Note that the other changes proposed in PI 167 were not incorporated as the sections referenced did not refer to "equipment" in this context but rather personnel, containers, and industrial trucks.

Section 9.6.6.1.4.2 was modified to clarify the requirements for flexible connectors. A resistance to ground was specified instead of an end-to-end resistance value to better represent the critical variable in defining the potential for a propagating brush discharge. Additional subsections were added, along with annex text, to differentiate between flexible connectors having a grounded reinforcing wire and those without, as the resistance to ground may be determined differently for each case. The annex text for 9.6.6.1.4.2 was expanded to reference NFPA 77 for charge to mass ratios for process operations and ISO 8031 for testing of flexible conductors. Further explanation of the difference between connectors with and without grounded reinforcing wires was also provided.

Public Inputs 48, 49 and 98 proposed similar revisions for this section. PIs 48 and 49 proposed differentiating between conductive and antistatic flexible connectors, but the clarification of the resistance determination was deemed to be a better way to address the issue. Furthermore, PI 49 was overly prescriptive in the requirements for antistatic flexible connectors. PI 98 proposed

adding a volume resistivity limit which would have created a second requirement within a single section, and this concern was addressed with the addition of 9.6.6.1.4.2(a).

A new section was added before 9.6.6.1.4.3 to explicitly allow for calculation of an alternative resistance to ground limit. This was done in recognition of the high material transfer rate that was assumed in defining the prescriptive resistance limit and to allow users to apply a different limit based on process-specific data. A table was provided to demonstrate the use of this alternative methodology.

The language in Section 9.6.6.1.4.3 (now 9.6.6.1.4.4) was modified to align with the changes made to 9.6.6.1.4.2 for consistency.

Section 9.6.6.1.4.4 (now 9.6.6.1.4.5) was revised to change the MIE threshold from 2000 mJ to 1000 mJ, as proposed in PI 168, with explanatory annex text. This is consistent with PI 168 and 169. This is consistent with Britton (1999) as a primary reference. The alternate reference provided in the substantiation for PI 168 and the proposed annex for PI 169 made reference to the incendivity of propagating brush discharges but did not demonstrate or quantify the issue beyond what was addressed in the Britton reference.

Public Input No. 134-NFPA 660-2026 [Section No. 9.6.6.1.2]

9.6.6.1.2

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

(1)* Hybrid mixtures and flammable gas/vapor atmospheres are not present.

(2)* Conductive particulate solids are not handled.

(3)* The nonconductive components do not result in isolation of conductive components from ground.

(4)* ~~The breakdown strength across nonconductive sheets, coatings, membranes, or pipe/vessel wall with thickness less than 0.3 in. (8 mm) does not exceed 4 kV, and the breakdown strength across nonconductive woven materials does not exceed 6 kV, when used in high surface charging processes.~~

Statement of Problem and Substantiation for Public Input

Industry is having great difficulty in determining if we meet this requirement, 4kV. In the field for existing assets, it is very difficult to measure this. Every dust collector we have is coated and not resulting in dust ignition events. NFPA should not have a requirement that is this challenging to understand and meet. Recommend task group to provide better guidance or delete the requirement.

Submitter Information Verification

Submitter Full Name: Julia Wiggen
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jan 02 15:50:07 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: Removing text as proposed would allow the use of materials that could create propagating brush discharges.

Public Input No. 139-NFPA 660-2026 [Section No. 9.6.6.1.2]

9.6.6.1.2

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

(1)* Hybrid mixtures and flammable gas/vapor atmospheres are not present.

(2)* Conductive particulate solids are not handled.

(3)* The nonconductive components do not result in isolation of conductive components from ground.

(4)* The breakdown strength across nonconductive sheets, coatings, membranes, or pipe/vessel wall with thickness less than 0.3 in. (8 mm) does not exceed 4 kV, and the breakdown strength across nonconductive woven materials does not exceed 6 kV, when used in high surface charging processes.

(5) The nonconductive components are less than 24 in. (610 mm) in length and conductive components shall be bonded.

Statement of Problem and Substantiation for Public Input

Similar to requirements of flexible connectors, a non-conductive component with <24 inches is not long enough to develop a static ignition concern. As long as the conductive components are grounded and bonded the risk is mitigated. Examples include glass and plexiglass sight glasses on gravity systems.

Submitter Information Verification

Submitter Full Name: Julia Wiggen
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jan 02 16:02:53 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: No sufficient justification for a blanket exclusion on nonconductive objects longer than 24" in all cases, nor to justify that 24" is sufficiently short to prevent propagating brush discharges.

Public Input No. 136-NFPA 660-2026 [Section No. 9.6.6.1.3]

9.6.6.1.3*

Bonding and grounding with a resistance of less than 1.0×10^6 ohms to ground shall be provided for conductive components when handling dusts with MIE <30 mJ .

Statement of Problem and Substantiation for Public Input

3rd party DHA facilitators are using this statement to require industry to test every conductive connection throughout entire facility for all dusts regardless of MIE. This is overly conservative and an unnecessary burden to take this approach. This PI improves the language of the requirement by being focused on the hazard of the material MIE.

Submitter Information Verification

Submitter Full Name: Julia Wiggen
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jan 02 15:54:42 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: Discharge mechanism of concern is capacitive spark discharge, so 30 mJ threshold is not relevant. (Capacitive spark discharges can have significantly higher energy dependent on capacitance and applied voltage)

Public Input No. 48-NFPA 660-2025 [Section No. 9.6.6.1.4.2]

9.6.6.1.4.2*

~~Flexible~~ Conductive flexible connectors used for pneumatic conveying, dust collection, or vacuum cleaning, re less of length, shall have an end-to-end resistance of less than 1.0×10^6 ohms per ISO-8031 even where an internal or external bonding wire connects the equipment to which the flexible connector is attached.

Statement of Problem and Substantiation for Public Input

To establish 2 different classes of hoses used in combustible dust: 1) Conductive & 2) Antistatic. Also to add test method ISO-8031.

Submitter Information Verification

Submitter Full Name: Carl Garrett
Organization: Flexaust
Street Address:
City:
State:
Zip:
Submittal Date: Wed Dec 17 14:16:44 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-38-NFPA 660-2026

Statement: Note: There is a separate revision (FR 39) that deletes 9.6.6.1.4.1 and A.9.6.6.1.4.1. This ballot item, FR 38, makes the other changes to 9.6.6.

Changes were made to section 9.6.6 and its annex to address the use of nonconductive equipment.

Section 9.6.6.1 was modified to specifically reference section 9.6.6.1.4 regarding flexible connectors where applicable, in response to PI 167. Note that the other changes proposed in PI 167 were not incorporated as the sections referenced did not refer to "equipment" in this context but rather personnel, containers, and industrial trucks.

Section 9.6.6.1.4.2 was modified to clarify the requirements for flexible connectors. A resistance to ground was specified instead of an end-to-end resistance value to better represent the critical variable in defining the potential for a propagating brush discharge. Additional subsections were added, along with annex text, to differentiate between flexible connectors having a grounded reinforcing wire and those without, as the resistance to ground may be determined differently for each case. The annex text for 9.6.6.1.4.2 was expanded to reference NFPA 77 for charge to mass ratios for process operations and ISO 8031 for testing of flexible conductors. Further explanation of the difference between connectors with and without grounded reinforcing wires was a provided.

Public Inputs 48, 49 and 98 proposed similar revisions for this section. PIs 48 and 49 proposed differentiating between conductive and antistatic flexible connectors, but the clarification of the resistance determination was deemed to be a better way to address the issue. Furthermore, PI 49 was overly prescriptive in the requirements for antistatic flexible connectors. PI 98 proposed adding a volume resistivity limit which would have created a second requirement within a single section, and this concern was addressed with the addition of 9.6.6.1.4.2(a).

A new section was added before 9.6.6.1.4.3 to explicitly allow for calculation of an alternative resistance to ground limit. This was done in recognition of the high material transfer rate that was assumed in defining the prescriptive resistance limit and to allow users to apply a different limit based on process-specific data. A table was provided to demonstrate the use of this alternative methodology.

The language in Section 9.6.6.1.4.3 (now 9.6.6.1.4.4) was modified to align with the changes made to 9.6.6.1.4.2 for consistency.

Section 9.6.6.1.4.4 (now 9.6.6.1.4.5) was revised to change the MIE threshold from 2000 mJ to 1000 mJ, as proposed in PI 168, with explanatory annex text. This is consistent with PI 168 and 169. This is consistent with Britton (1999) as a primary reference. The alternate reference provided in the substantiation for PI 168 and the proposed annex for PI 169 made reference to the incendivity of propagating brush discharges but did not demonstrate or quantify the issue beyond what was addressed in the Britton reference.

Public Input No. 98-NFPA 660-2025 [Section No. 9.6.6.1.4.2]

9.6.6.1.4.2*

Flexible connectors used for pneumatic conveying, dust collection, or vacuum cleaning, regardless of length, shall have an end-to-end resistance of less than 1.0×10^6 ohms ~~even where an internal or external~~ . Where this is accomplished through an integral bonding wire which connects the ~~equipment to which~~ ends of the flexible connector ~~is attached.~~ , the connector shall also have a maximum volume resistivity of 1.0 x 10^8 ohm meters.

Statement of Problem and Substantiation for Public Input

The original writing only addresses end to end flexible connector resistance. This leaves users open to hazards associated with surface charges (exterior tracking, brush discharges, propagating brush discharges) since the end to end resistance can commonly be only a few ohms due to the presence of a dedicated internal wire. Justification for the level of 10^8 volume resistivity (NFPA 77 refers to it as wall resistivity, but given the units I believe it is referring to a volume resistivity of the wall instead of a surface resistivity which would be given in ohms (or preferably ohms/square)) is beyond me, however it algins with NFPA 77 Explanatory material A.10.2

Submitter Information Verification

Submitter Full Name: Drake Bernhard
Organization: Grain Processing Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Dec 23 11:07:41 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-38-NFPA 660-2026

Statement: Note: There is a separate revision (FR 39) that deletes 9.6.6.1.4.1 and A.9.6.6.1.4.1. This ballot item, FR 38, makes the other changes to 9.6.6.

Changes were made to section 9.6.6 and its annex to address the use of nonconductive equipment.

Section 9.6.6.1 was modified to specifically reference section 9.6.6.1.4 regarding flexible connectors where applicable, in response to PI 167. Note that the other changes proposed in PI 167 were not incorporated as the sections referenced did not refer to "equipment" in this context but rather personnel, containers, and industrial trucks.

Section 9.6.6.1.4.2 was modified to clarify the requirements for flexible connectors. A resistance to ground was specified instead of an end-to-end resistance value to better represent the critical variable in defining the potential for a propagating brush discharge. Additional subsections were added, along with annex text, to differentiate between flexible connectors having a grounded reinforcing wire and those without, as the resistance to ground may be determined differently for each case. The annex text for 9.6.6.1.4.2 was expanded to reference NFPA 77 for charge to mass ratios for process operations and ISO 8031 for testing of flexible conductors. Further explanation of the difference between connectors with and without grounded reinforcing wires was also provided.

Public Inputs 48, 49 and 98 proposed similar revisions for this section. PIs 48 and 49 proposed

differentiating between conductive and antistatic flexible connectors, but the clarification of the resistance determination was deemed to be a better way to address the issue. Furthermore, PI 49 was overly prescriptive in the requirements for antistatic flexible connectors. PI 98 proposed adding a volume resistivity limit which would have created a second requirement within a single section, and this concern was addressed with the addition of 9.6.6.1.4.2(a).

A new section was added before 9.6.6.1.4.3 to explicitly allow for calculation of an alternative resistance to ground limit. This was done in recognition of the high material transfer rate that was assumed in defining the prescriptive resistance limit and to allow users to apply a different limit based on process-specific data. A table was provided to demonstrate the use of this alternative methodology.

The language in Section 9.6.6.1.4.3 (now 9.6.6.1.4.4) was modified to align with the changes made to 9.6.6.1.4.2 for consistency.

Section 9.6.6.1.4.4 (now 9.6.6.1.4.5) was revised to change the MIE threshold from 2000 mJ to 1000 mJ, as proposed in PI 168, with explanatory annex text. This is consistent with PI 168 and 169. This is consistent with Britton (1999) as a primary reference. The alternate reference provided in the substantiation for PI 168 and the proposed annex for PI 169 made reference to the incendivity of propagating brush discharges but did not demonstrate or quantify the issue beyond what was addressed in the Britton reference.

Public Input No. 49-NFPA 660-2025 [New Section after 9.6.6.1.4.3]

TITLE OF NEW CONTENT

9.6.6.1.4.3 Antistatic flexible, metallic spiral hose may be used for pneumatic conveying, dust collection, or vacuum cleaning, provided it meets the following criteria:

(1) Metallic spiral must be > 0.5 mm diameter

(2) Spiral must be grounded both ends

(3) Wall thickness below the spiral must be > 0.5 mm

(4) Spiral pitch must be < 40 mm

(5) Spiral must be embedded in a homogeneous, antistatic flexible material with a volume resistivity of < 10 E 9 ohms per ISO 8031

Statement of Problem and Substantiation for Public Input

Reasons for adding 9.6.6.1.4.3:
1. The use of fully conductive (less than 1.0 × 106) flexible connectors / hoses requires these connectors be manufactured from materials with a very high loading of carbon black, which makes them brittle and prone to failure from continuous flexing.
2. The resulting flexible connector failure will likely cause an unsafe condition by allowing excess combustible dust to enter the work area.
3. Most carbon black is considered a carcinogen and is not acceptable for food contact applications making conductive hoses unacceptable in many food and pharmaceutical processing facilities.
4. Carbon black conductive hoses cannot be made clear and do not allow the operators to visualize clogs or other unsafe conditions.
5. Carbon black conductive hoses slough off and mark equipment and contaminate the media being transported.

Submitter Information Verification

Submitter Full Name: Carl Garrett
Organization: Flexaust
Street Address:
City:
State:
Zip:
Submittal Date: Wed Dec 17 14:19:35 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: The revisions here are too prescriptive but revisions to address this concern have been made in FR 38.

Public Input No. 168-NFPA 660-2026 [Section No. 9.6.6.1.4.4]

9.6.6.1.4.*

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

(1) The dust has an MIE greater than ~~2000 mJ~~ 1000 mJ .

(2) The maximum powder transfer velocity is less than 2000 ft/min (10 m/sec).

Statement of Problem and Substantiation for Public Input

The 2000 mJ criterion is tilted towards a single apparatus supplier while a different and acceptable criterion (closer to 1000 mJ) would be of general use and would be consistent with Larry Britton's book "Avoiding Static Ignition Hazards in Chemical Operations" (many instances) which states the maximum EFFECTIVE energy of PBDs is probably about 1000 mJ.

The stored energy of a PBD can be much greater than 1000 mJ but only a small part of the stored energy is released in a small enough volume to contribute to dust evaporation/decomposition and ignition. Ian Pavey's paper "Propagating brush discharges in flexible hoses,"" Journal of Electrostatics May 2009, 251–255"" reports measured stored energies between 12 mJ and 2000 mJ which is quite consistent with an effective energy of 1000 mJ given the large volume over which the PBD dissipates its energy. Provided NFPA 660 does not specify a criterion above 1200-1400 mJ all other MIE apparatus described in ASTM E2019 should be able to make the measurement. Most were designed to measure MIEs somewhat above 1000 mJ, above which dusts are not regarded as significant static ignition risks.

NFPA 660's MIE criterion cannot be for a polydispersion (e.g., 5 – 500 microns) but should be measured for the finest "significant" size fraction present. Suggest the finest 20 wt% but some other number could be used. The dust fraction tested should be sub-200 mesh (or as specified in ASTM E2019). "

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 169-NFPA 660-2026 [Section No. A.9.6.6.1.4.4]	

Submitter Information Verification

Submitter Full Name: Eric Winter
Organization: Corteva Agriscience
Affiliation: NFPA 77TG#8
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jan 06 15:08:20 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: FR-38-NFPA 660-2026

Statement: Note: There is a separate revision (FR 39) that deletes 9.6.6.1.4.1 and A.9.6.6.1.4.1. This ballot item, FR 38, makes the other changes to 9.6.6.

Changes were made to section 9.6.6 and its annex to address the use of nonconductive equipment.

Section 9.6.6.1 was modified to specifically reference section 9.6.6.1.4 regarding flexible connectors where applicable, in response to PI 167. Note that the other changes proposed in PI 167 were not incorporated as the sections referenced did not refer to "equipment" in this context but rather personnel, containers, and industrial trucks.

Section 9.6.6.1.4.2 was modified to clarify the requirements for flexible connectors. A resistance to ground was specified instead of an end-to-end resistance value to better represent the critical variable in defining the potential for a propagating brush discharge. Additional subsections were added, along with annex text, to differentiate between flexible connectors having a grounded reinforcing wire and those without, as the resistance to ground may be determined differently for each case. The annex text for 9.6.6.1.4.2 was expanded to reference NFPA 77 for charge to mass ratios for process operations and ISO 8031 for testing of flexible conductors. Further explanation of the difference between connectors with and without grounded reinforcing wires was also provided.

Public Inputs 48, 49 and 98 proposed similar revisions for this section. PIs 48 and 49 proposed differentiating between conductive and antistatic flexible connectors, but the clarification of the resistance determination was deemed to be a better way to address the issue. Furthermore, PI 49 was overly prescriptive in the requirements for antistatic flexible connectors. PI 98 proposed adding a volume resistivity limit which would have created a second requirement within a single section, and this concern was addressed with the addition of 9.6.6.1.4.2(a).

A new section was added before 9.6.6.1.4.3 to explicitly allow for calculation of an alternative resistance to ground limit. This was done in recognition of the high material transfer rate that was assumed in defining the prescriptive resistance limit and to allow users to apply a different limit based on process-specific data. A table was provided to demonstrate the use of this alternative methodology.

The language in Section 9.6.6.1.4.3 (now 9.6.6.1.4.4) was modified to align with the changes made to 9.6.6.1.4.2 for consistency.

Section 9.6.6.1.4.4 (now 9.6.6.1.4.5) was revised to change the MIE threshold from 2000 mJ to 1000 mJ, as proposed in PI 168, with explanatory annex text. This is consistent with PI 168 and 169. This is consistent with Britton (1999) as a primary reference. The alternate reference provided in the substantiation for PI 168 and the proposed annex for PI 169 made reference to the incendivity of propagating brush discharges but did not demonstrate or quantify the issue beyond what was addressed in the Britton reference.

Public Input No. 132-NFPA 660-2026 [New Section after 9.6.6.4.3]

Add clarity on personnel grounding requirement for type B FIBC bags.

Add section to type B FIBC bags, e.g. 9.6.6.4.3.3 to state, Type B FIBCs shall be permitted to be used without personnel grounding when material minimum ignition energy is >30 mJ. (alternatively could be added to section 9.6.6.4.7 referring to all FIBCs in the event a Type B,C,D bag is used for MIE > 30 mJ).

-

Statement of Problem and Substantiation for Public Input

Justification: FIBC Type B bags are labeled with a common label from supplier that states, "All conductive objects, including personnel shall be earthed during FIBC filling and emptying operations (see IEC TS 60079-32-1 for guidance on earthing)". This statement on labels and lack of further clarity in NFPA leads to users of FIBC Type B bags to believe personnel grounding is required regardless of dust MIE. With FIBC Type B bags permitted for MIE >3 mJ, it is common for bags to be used for MIE >30 mJ which does not present a risk requiring personnel bonding. Adding the proposed statement will provide clarity to the misleading FIBC Type B bag labels throughout industry to prevent unnecessary and burdensome personnel grounding measures.

Submitter Information Verification

Submitter Full Name: Julia Wiggen
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jan 02 15:31:49 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: Requirements for grounding of personnel are already addressed in 9.6.6.3 and associated annex.

Public Input No. 89-NFPA 660-2025 [Section No. 9.8.2.4]

~~9.8.2.4~~ –

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

Statement of Problem and Substantiation for Public Input

It is suggested to delete this requirement. The explosion hazard protection requirements are already stated, so stating it again is redundant. Every fabric media dust collector is a potential fire hazard, but it is not a fundamental requirement to provide fire protection to every dust collector. Those decisions are jointly made between the owner and the insurance carrier and are evaluated during the DHA.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 90-NFPA 660-2025 [New Section after 21.9.8.2.3]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 22 16:47:31 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: This requirement is when both hazards exist simultaneously and must be mitigated. A deflagration suppression system installed does not always react to a fire inside an AMS and both hazards must be addressed.

Public Input No. 44-NFPA 660-2025 [Chapter 10]

Chapter 10 Emergency Planning and Response

10.1 Retroactivity.

This chapter and the corresponding X.10 sections of the industry- and commodity-specific chapters shall be applied retroactively to new and existing facilities and processes.

10.2 Emergency Response Plan.

10.2.1*

A written emergency response plan shall be developed for preparing for and responding to work-related emergencies including, but not limited to, fires, flash fires, and explosions.

10.2.1.1

The emergency response plan shall be available on-site or electronically.

10.2.1.2

The emergency response plan shall include, but not be limited to, the following:

(1)* A means of notification for occupants in the event of fire and explosion

(2) A preplanned evacuation assembly area

(3) A person(s) designated to notify emergency responders, including the fire department

(4) A facility layout drawing(s) showing egress routes, hazardous chemical locations, and fire protection equipment

(5) Location of a safety data sheet(s) for hazardous chemicals

(6) An emergency telephone number(s)

(7) Emergency response duties for occupants

(8) A person(s) designated to meet the offsite emergency responder(s) to coordinate the incident

10.2.2

The emergency response plan and procedures shall be reviewed and validated at least annually and as required by process changes.

10.2.3

The emergency response plan shall be shared with relevant local community officials and emergency response agencies.

10.3 Reserved.

****SEE ATTACHED FILE****

Additional Proposed Changes

File Name	Description	Approved
660_CMD-FUN_PC_255_Rejected_but_Held.pdf	NFPA 660 CMD-FUN PC No. 255	

Statement of Problem and Substantiation for Public Input

NOTE: This Public Input appeared as "Reject but Held" in the Public Comment No. 255 of the F2024 Second Draft Report for NFPA 660 per Regs. at 4.4.8.3.1.

A task group was formed by the correlating committee to combine existing firefighting and emergency planning guidance and requirements into a fundamentals chapter 10. This information is based upon that group's efforts.

Submitter Information Verification

Submitter Full Name: NFPA Holds
Organization: Holds
Street Address:
City:
State:
Zip:
Submittal Date: Tue Dec 16 16:28:17 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-31-NFPA 660-2026

Statement: The requirements throughout NFPA 660 pertaining to emergency planning and response have been consolidated into Chapter 10. The Technical Committee on Fundamentals of Combustible Dust asks the other Technical Committees to consider removing duplicative requirements from the other chapters.

Public Comment No. 225-NFPA 660-2024 [Chapter 10]

Chapter

~~10~~ ~~Reserved~~

~~**10.1**~~

10 Emergency Planning and Manual Firefighting

10.1 Emergency Planning & Response

10.2.1 A written emergency response plan shall be developed for preparing for and responding to work-related emergencies including, but not limited to, fires, flash fires, and explosions.

10.2.2 Emergency planning and response shall be in accordance with NFPA 600, Standard on Facility Fire Brigades (if applicable), and NFPA 1660, Standard on Continuity, Emergency, and Crisis Management.

10.2.3 The emergency response plan shall include, but not be limited to, the following:

10.2.3.1 A means of notification for occupants in the event of fire and explosion

10.2.3.2 A preplanned evacuation assembly area

10.2.3.3 A person(s) designated to notify emergency responders, including the fire department

10.2.3.4 A facility layout drawing(s) showing egress routes, hazardous chemical locations, and fire protection equipment

10.2.3.5 Location of a safety data sheet(s) for hazardous chemicals

10.2.3.6 Plant management emergency telephone number(s)

10.2.3.7 Emergency response duties for occupants

10.2.3.8 A person(s) designated to meet the offsite emergency responder(s) to coordinate the incident

10.2.3.9 Interdepartmental and interplant cooperation

10.2.3.10 Cooperation of outside agencies

10.2.3.11 The release of accurate information to the public

10.2.4 The emergency response plan shall address locations for remote shutoff of supply systems when any of the following are present:

10.2.4.1 Water (water from all types of sources)

10.2.4.2 Electrical materials

10.2.4.3 Flammable gases

10.2.4.4 Ignitable (flammable or combustible) liquids

10.2.4.5 Toxic materials

10.2.4.6 Other hazardous materials

10.3 Emergency Response Plan and Training

10.3.1 Employee health and safety in operations shall depend on the recognition of actual or potential hazards, the control or elimination of those hazards, and the training of employees on safe working procedures.

10.3.2 The emergency response plan shall be available on-site or electronically.

10.3.3 Fires, when discovered, shall be reported promptly to facility management and emergency responders, including the fire department.

10.3.4 If a fire cannot be controlled promptly in its incipient stage, the endangered structure(s) shall be evacuated.

10.3.5 Emergency drills shall be performed annually by plant personnel and validated as required by process changes.

10.3.6 Plant personnel, including management, supervisors, and maintenance and operating personnel, shall be trained to participate in plans for controlling plant emergencies.

10.3.7 The emergency response plan shall be shared with relevant local community officials and emergency response agencies.

10.3.8 Malfunctions of the process shall be simulated and emergency actions undertaken as necessary.

10.3.9 Disaster drills that simulate a major catastrophic situation shall be undertaken periodically with the cooperation and participation of public fire, police, and other local community emergency units and nearby cooperating plants.

10.3.10 Specialized training for the public fire department(s) and industrial fire brigades shall be warranted when the facility-specific hazards dictate that the methods to control and extinguish a fire are outside of their normal arena of traditional firefighting.

10.4 Manual Firefighting

10.4.1 Those individuals responsible for manual fire suppression shall have a fire protection plan.

10.4.2 Proper protective clothing, respiratory protection, and adequate eye protection shall be used by all responding firefighting

personnel assigned to a combustible metal fire equipped to the requirements of NFPA 600, Standard on Facility Fire Brigades (if applicable) or NFPA 1081, Standard for Facility Fire Brigade Member Professional Qualifications.

10.4.3 The evaluation of the risk to facility personnel and firefighters shall be made based on discussions with the responding fire department(s) and review of the DHA.

10.4.4 The potential effectiveness of manual firefighting shall be assessed by experienced firefighting personnel after reviewing the hazard assessment documentation developed in accordance with the DHA.

10.4.5 For materials that can be effectively extinguished with water, hose streams shall be used with great care to avoid creating dust clouds or causing structural damage to bins.

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

10.4.5.2 Fire responders shall be cautioned when using straight stream nozzles in the vicinity of combustible dust accumulations that dust clouds can be formed and can be ignited by any residual smoldering or fire.

10.4.5.3 Straight stream nozzles or combination nozzles shall be permitted to be used to reach fires in locations that are otherwise inaccessible with the nozzles specified in 11.8.10.3.5.

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

10.4.6 Where firefighting water or wet product can accumulate in the system, the vessel, pipe supports, and drains shall be designed to support the additional water weight in accordance with NFPA 91, Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists and Particulate Solids.

10.5 Firefighting Operations / Activities

10.5.1 Incipient firefighting techniques shall be established for fighting different types of fires that may be present at a facility including:

10.5.2 Clothing Fires.

10.5.2.1 Emergency procedures for handling clothing fires shall be established as part of the plan.

10.5.2.2 If deluge showers are installed, they shall be located away from dry metal powder–processing and metal powder–handling areas if water is not an effective extinguishing agent.

10.5.2.3 The plan shall address locations for remote shutoff of supply systems when any of the following are present:

- Water (water from all types of sources)
- Electrical materials
- Flammable gases
- Ignitible (flammable or combustible) liquids
- Toxic materials
- Other hazardous materials

10.5.2.4 In plant areas where water is excluded, fire blankets shall be distributed for extinguishing clothing fires.

10.5.2.5 Elevator leg fires

10.5.2.5.1 Burning material shall not be transferred into legs.

10.5.2.6 Conveyor belt fires

10.5.2.7 Dryer fires

10.5.2.8 Concrete bin or silo and steel tank fires

10.5.2.9 Concrete Bin or Silo and Steel Tank Smolders

10.5.2.10 Fumigant or Chemical Fires

10.5.2.11 Water Gas Reaction

10.5.2.12 Bearing Fires

10.5.2.12.1 Bearing fires shall be extinguished with a gentle application of water fog onto the bearing for cooling.

10.5.2.12.2 If water is not available, other means of extinguishment shall be permitted to be used on the bearing fire, provided caution is taken to avoid the suspension of combustible dust.

10.5.2.12.3 If the bearing is located inside equipment, material flow shall be stopped, equipment shall be shut down, and extreme caution shall be used when equipment is opened.

10.6 Agricultural and Food Processing

10.7 Combustible Metals

10.7.1 Local emergency response agency notification shall be required for any operation storing or processing 5 lb (2.27 kg) or more of powder, dusts, fines, or alkali metal in any form or 500 lb (227 kg) or more of chips or turnings.

10.7.2 The following list of actions to be performed as well as information regarding the hazards of combustible metals shall be provided to emergency responders for the safe handling of combustible metal fires:

10.7.2.1 Perform a size-up, evaluation, and identification of metals involved in the fire.

10.7.2.2 Ensure control of utilities (e.g., water, gases, power, etc.) to affected areas.

10.7.2.3 Review safety data sheets (SDSs) for the involved products, and if available, contact those familiar with the product and hazards.

10.7.2.4 Evaluate whether the fire can be isolated safely and allowed to burn out.

10.7.2.5 Determine whether uninvolved product and exposures — other than alkali metals — can be protected by hose streams, after an adequate review has been completed to ensure any runoff from hose streams does not come into contact with burning or molten combustible metal.

10.7.2.6 Do not apply water to alkali metals in either a fire or non-fire situation.

10.7.2.7 Use an inert blanket, such as argon, helium, or nitrogen, if the fire is burning in a closed container, such as a dust collection system, to control the fire where an adequate delivery system is available and personnel safety is considered.

10.7.2.8 Evaluate the potential for explosion.

10.7.2.9 Use extreme caution with fires involving combustible-metal powders, dusts, and fines because of the possibility of explosions, especially if the product becomes airborne and there is an available ignition source.

10.7.2.10 Evaluate whether there is adequate drainage to prevent the contact of water with burning metal that is not compatible for protecting exposures.

10.7.2.11 Evaluate the fire to determine whether the fire can burn itself out naturally to minimize hazards to personnel and losses to exposures.

10.7.2.12 Evaluate the control and shutdown of both domestic and fire protection water systems to prevent unintended contact of water with burning or molten combustible metal.

10.7.2.13 Use extinguishing agents that are compatible with the hazards present.

10.7.2.14 Use extinguishing agents for containment of small and incipient fires.

10.7.2.15 Use extreme caution with fires involving large quantities of product within structures.

10.7.2.16 Most fires involving combustible metals cannot be extinguished in a manner other than by providing an inert atmosphere of argon or helium — and nitrogen for alkali metals or iron — if the product is dry.

10.7.2.17 Most fires can be controlled by application of argon or helium — or nitrogen for alkali metals or iron— or by the development of an oxide crust.

10.7.2.18 The temperature of the metals involved in the fire can remain extremely high and the fire can flare up again if the product is disturbed prior to complete oxidation of the product or self-extinguishment.

10.7.2.19 Water in contact with molten combustible metals will result in violent steam explosions, and can cause hydrogen explosions and reactions.

10.7.2.20 Isolate the metal as much as possible; large fires might be impossible to extinguish.

10.7.2.21 The physical state of the product, such as chips, powder, fines, and dust, and the quantity of product involved in the fire, potentially involved in the fire, or both, are extremely important factors for emergency responders.

10.7.2.22 Fires involving large quantities of product within structures can result in rapid heat buildup and smoke generation beyond that normally encountered in fires involving ordinary combustibles.

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

10.7.3 Firefighting Activities.

10.7.3.1 Trained employees shall be permitted to fight incipient-stage fires, provided the fire can be controlled with portable extinguishers or other dry extinguishing agent.

10.7.3.2 In case of fire in reactive metal chips, turnings, or powder compact, the pan or tray shall not be disturbed or moved, except by an individual knowledgeable in the fire aspects of combustible metals, until the fire has been extinguished and the material has cooled to ambient temperature.

10.7.3.3 Combustible-metal fires beyond the incipient stage shall be fought by professional firefighters, specially trained fire brigade personnel, or both.

10.7.3.4 Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residue has cooled to room temperature.

10.7.3.5 Fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

10.7.3.6 Burning combustible metals will burn through material used in the construction of most firefighter protective clothing. Some features (e.g., heavy quilted linings, aluminized outer shells) can reduce this risk. The self-contained breathing apparatus (SCBA) facepiece eye protection worn by firefighters adequately protects against the effects of a lithium fire, with the exception of the intense light given off by burning lithium. (See NFPA 1500.)

10.7.3.7 Specific testing indicates that white-light levels emitted from burning lithium exceed recommended levels, and extended lithium fire experience has shown that this intense light can cause serious damage to unprotected eyes. A clip-on adapter over an SCBA facepiece with a shaded glass lens equivalent to a No. 6 welding lens has been used successfully to reduce such hazards. A darker lens tends to obstruct the firefighter's view to an unacceptable degree.

10.7.3.8 Fire residues shall be disposed of in accordance with federal, state, and local regulations.

10.7.3.9 When drums or tote bins of burning materials can be moved safely, they shall be moved away from processing equipment and out of buildings as rapidly as possible.

10.7.4 Alkali Metals Firefighting Procedures.

10.7.4.1 While an alkali-metal fire is being fought, every effort shall be made to avoid splattering the burning alkali metals.

10.7.4.2 Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residues have cooled to room temperature.

10.7.5 Firefighting Organization.

10.7.5.1 Only trained personnel shall be permitted to engage in fire control activity.

10.7.5.2 Personnel other than trained personnel shall be evacuated from the area.

10.7.5.3 Training shall emphasize the different types of fires anticipated and the appropriate agents and techniques to be used.

10.7.5.4 Firefighting personnel shall be given training in the extinguishment of test fires set in a safe location away from manufacturing buildings.

10.7.5.5 Training shall include all possible contingencies.

10.7.5.6 If professional or volunteer firefighters are admitted onto the property in the event of a fire emergency, their activity shall be directed by a unified incident command that includes knowledgeable plant personnel.

10.7.5.7 The following information on the safe handling of combustible metal fires shall be provided for emergency preparedness planning:

10.7.5.8 Water, when applied to most burning combustible metals, results in an increase in burning intensity and possible explosion.

10.7.5.9 Water applied to alkali metals not involved in the fire will result in hazardous decomposition, ignition, or explosion.

10.7.5.10 Application of carbon dioxide on combustible-metal fire adds to the intensity of the burning. Most combustible metals ignite and burn in 100 percent carbon dioxide atmospheres.

10.7.5.11 Dry chemical extinguishers react with alkali metals and intensify the fire.

10.7.5.12 Dry chemical extinguishers utilized on non-alkali metal fires are ineffective in controlling the metal fire but might be effective where ignitable (flammable or combustible) liquids are used and the metal is not yet involved in the fire.

10.7.5.13 Halogenated extinguishing agents used on alkali metals can result in an explosion.

10.7.5.14 Halogenated extinguishing agents will have a detrimental effect on other combustible metal fires, with the decomposition producing hazardous by-products.

10.7.5.15 A primary metal fire displays intense orange-to-white flame and can be associated with a heavy or large production of white or gray smoke.

10.7.5.16 When water is applied to non-alkali combustible metal, it can disassociate to the basic compounds, oxygen and hydrogen. Similar results occur with carbon dioxide.

10.7.5.17 When water is applied to alkali metals, hydroxides and hydrogen are generated immediately.

10.7.5.18 Fires involving combustible metals that contain moisture exhibit more intense burning characteristics than dry product.

10.7.5.19 Extreme heat can be produced. For example, burning titanium and zirconium have the potential to produce temperatures in excess of 7000°F (3857°C) and 8500°F (4690°C), respectively.

10.7.5.20 Dusts, fines, and powders of combustible metals present an explosion hazard, especially in confined spaces.

10.7.5.21 Dusts, fines, and powders of titanium and zirconium present extreme hazards; zirconium powders have ignition temperatures as low as 68°F (20°C). Static electric charges can ignite some dusts and powders of titanium and zirconium.

10.7.5.22 Zirconium and titanium powder can exhibit pyrophoric characteristics.

10.7.5.23 Turnings and chips of combustible metals can ignite and burn with intensity, especially if coated with a petroleum-based oil, with some spontaneous combustion having been observed.

10.7.5.24 With the exception of alkali metals, the larger the product, the smaller the likelihood of ignition. Bars, ingots, heavy castings, and thick plates and sheets are virtually impossible to ignite and, in most cases, self-extinguish when the heat source is removed.

10.7.5.25 The sponge product of most combustible metals burns at a slower rate but still produces tremendous heat.

10.7.5.26 Burning combustible metals can extract moisture from concrete and similar products that can intensify burning and cause spalling and explosion of the products and spewing of chunks of concrete.

10.7.5.27 Burning metal destroys asphalt and extracts moisture from rock which may explode spewing rock fragments.

10.7.5.28 Most fires involving non-alkali combustible metals usually cannot be extinguished, and unless they are placed in an inert atmosphere of argon or helium, they can only be controlled.

10.7.5.29 Fires involving large quantities of metals shall be allowed to cool for at least 24 hours prior to being disturbed to prevent re-ignition.

10.7.5.30 Fires will oxidize most metals and provide a protective covering limiting open burning.

10.7.5.31 Alkali metal fires can be extinguished with the suitable extinguishing agents correctly applied.

10.7.5.32 Combustible metal fines and powders that are stored and contain moisture can produce hydrogen gas.

10.7.5.33 Combustible metal fines and dusts that are reduced (not oxidized) and that come into contact with other metal oxides can result in thermite reactions.

10.7.5.34 Prior to the arrival of alkali metals on site, the local fire department shall be notified of the presence of water-reactive materials on site and shall be notified of the hazards of using water on alkali-metal fires.

10.8 Sulfur

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

10.8.1.1 Inert gas system in accordance with NFPA 69, Standard on Explosion Prevention Systems.

10.8.1.2 Steam extinguishing system capable of delivering a minimum of 2.5 lb./min (1.13 kg/min) of steam per 100 ft3 (2.83 m3) of volume

10.8.1.3 Rapid sealing of the enclosure to exclude air

10.8.2 Snuffing Steam and Sealing Steam Precautions.

10.8.3 The vent systems on enclosed sulfur tanks and sulfur pits shall be designed to allow the required snuffing steam rate or sealing steam rate to vent without overpressuring the enclosure.

10.8.3.1 The vent systems shall also be designed for proper operation during normal operation.

10.8.4 Water Extinguishing Precautions.

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

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

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

10.8.5 Dry Chemical Extinguishers.

10.8.5.1 Where sulfur is being heated by a combustible heat transfer fluid, dry chemical extinguishers complying with NFPA 17 shall be provided.

10.8.6 It shall be permitted to use straight stream nozzles or combination nozzles to reach fires in locations that are otherwise inaccessible.

10.9 Wood Processing and Woodworking Facilities

10.10 Combustible Dusts and Particulate Solids Not Otherwise Specified

Additional Proposed Changes

File Name	Description	Approved
NFPA_660_Firefighting_Task_Group_01042024_-_revisions.docx	Word version of requirements and annex material	

Statement of Problem and Substantiation for Public Comment

A task group was formed by the correlating committee to combine existing firefighting and emergency planning guidance and requirements into a fundamentals chapter 10. This information is based upon that group's efforts.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 285-NFPA 660-2024 [New Section after A.9.9.6.6]	
Public Comment No. 302-NFPA 660-2024 [New Section after 10.1]	
Public Comment No. 309-NFPA 660-2024 [New Section after 11.9.9.5]	
Public Comment No. 314-NFPA 660-2024 [New Section after 13.9.9.5.2.3]	
Public Comment No. 316-NFPA 660-2024 [New Section after 14.9.9.7.7]	
Public Comment No. 317-NFPA 660-2024 [New Section after 15.9.10.2]	

Related Item

- Correlating Note/Task Group

Submitter Information Verification

Submitter Full Name: Timothy Myers
Organization: Exponent, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jan 03 17:06:16 EST 2024
Committee: CMD-FUN

Committee Statement

Committee Action: Rejected but held

Resolution: Although the committee agrees that this material should be consolidated into Chapter 10, this is too substantial to change at the Second Draft stage and is being held for the next edition.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.1 Emergency Planning & Response

10.2.1 A written emergency response plan shall be developed for preparing for and responding to work-related emergencies including, but not limited to, fires, flash fires, and explosions.

10.2.2 Emergency planning and response shall be in accordance with NFPA 600, *Standard on Facility Fire Brigades* (if applicable), and NFPA 1660, *Standard on Continuity, Emergency, and Crisis Management*.

10.2.3 The emergency response plan shall include, but not be limited to, the following:

10.2.3.1 A means of notification for occupants in the event of fire and explosion

10.2.3.2 A preplanned evacuation assembly area

10.2.3.3 A person(s) designated to notify emergency responders, including the fire department

10.2.3.4 A facility layout drawing(s) showing egress routes, hazardous chemical locations, and fire protection equipment

10.2.3.5 Location of a safety data sheet(s) for hazardous chemicals

10.2.3.6 Plant management emergency telephone number(s)

10.2.3.7 Emergency response duties for occupants

10.2.3.8 A person(s) designated to meet the offsite emergency responder(s) to coordinate the incident

10.2.3.9 Interdepartmental and interplant cooperation

10.2.3.10 Cooperation of outside agencies

10.2.3.11 The release of accurate information to the public

10.2.4 The emergency response plan shall address locations for remote shutoff of supply systems when any of the following are present:

10.2.4.1 Water (water from all types of sources)

10.2.4.2 Electrical materials

10.2.4.3 Flammable gases

10.2.4.4 Ignitable (flammable or combustible) liquids

10.2.4.5 Toxic materials

10.2.4.6 Other hazardous materials

10.3 Emergency Response Plan and Training

10.3.1 Employee health and safety in operations shall depend on the recognition of actual or potential hazards, the control or elimination of those hazards, and the training of employees on safe working procedures.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.3.2 The emergency response plan shall be available on-site or electronically.

10.3.3 Fires, when discovered, shall be reported promptly to facility management and emergency responders, including the fire department.

10.3.4 If a fire cannot be controlled promptly in its incipient stage, the endangered structure(s) shall be evacuated.

10.3.5 Emergency drills shall be performed annually by plant personnel and validated as required by process changes.

10.3.6 Plant personnel, including management, supervisors, and maintenance and operating personnel, shall be trained to participate in plans for controlling plant emergencies.

10.3.7 The emergency response plan shall be shared with relevant local community officials and emergency response agencies.

10.3.8 Malfunctions of the process shall be simulated and emergency actions undertaken as necessary.

10.3.9 Disaster drills that simulate a major catastrophic situation shall be undertaken periodically with the cooperation and participation of public fire, police, and other local community emergency units and nearby cooperating plants.

10.3.10 Specialized training for the public fire department(s) and industrial fire brigades shall be warranted when the facility-specific hazards dictate that the methods to control and extinguish a fire are outside of their normal arena of traditional firefighting.

10.4 Manual Firefighting

10.4.1 Those individuals responsible for manual fire suppression shall have a fire protection plan.

10.4.2 Proper protective clothing, respiratory protection, and adequate eye protection shall be used by all responding firefighting personnel assigned to a combustible metal fire equipped to the requirements of NFPA 600, *Standard on Facility Fire Brigades* (if applicable) or NFPA 1081, *Standard for Facility Fire Brigade Member Professional Qualifications*.

10.4.3 The evaluation of the risk to facility personnel and firefighters shall be made based on discussions with the responding fire department(s) and review of the DHA.

10.4.4 The potential effectiveness of manual firefighting shall be assessed by experienced firefighting personnel after reviewing the hazard assessment documentation developed in accordance with the DHA.

10.4.5 For materials that can be effectively extinguished with water, hose streams shall be used with great care to avoid creating dust clouds or causing structural damage to bins.

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

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.4.5.2 Fire responders shall be cautioned when using straight stream nozzles in the vicinity of combustible dust accumulations that dust clouds can be formed and can be ignited by any residual smoldering or fire.

10.4.5.3 Straight stream nozzles or combination nozzles shall be permitted to be used to reach fires in locations that are otherwise inaccessible with the nozzles specified in 11.8.10.3.5.

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

10.4.6 Where firefighting water or wet product can accumulate in the system, the vessel, pipe supports, and drains shall be designed to support the additional water weight in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists and Particulate Solids*.

10.5 Firefighting Operations / Activities

10.5.1 Incipient firefighting techniques shall be established for fighting different types of fires that may be present at a facility including:

10.5.2 Clothing Fires.

10.5.2.1 Emergency procedures for handling clothing fires shall be established as part of the plan.

10.5.2.2 If deluge showers are installed, they shall be located away from dry metal powder–processing and metal powder–handling areas if water is not an effective extinguishing agent.

10.5.2.3 The plan shall address locations for remote shutoff of supply systems when any of the following are present:

- Water (water from all types of sources)
- Electrical materials
- Flammable gases
- Ignitible (flammable or combustible) liquids
- Toxic materials
- Other hazardous materials

10.5.2.4 In plant areas where water is excluded, fire blankets shall be distributed for extinguishing clothing fires.

10.5.2.5 Elevator leg fires

10.5.2.5.1 Burning material shall not be transferred into legs.

10.5.2.6 Conveyor belt fires

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.5.2.7 Dryer fires

10.5.2.8 Concrete bin or silo and steel tank fires

10.5.2.9 Concrete Bin or Silo and Steel Tank Smolders

10.5.2.10 Fumigant or Chemical Fires

10.5.2.11 Water Gas Reaction

10.5.2.12 Bearing Fires

10.5.2.12.1 Bearing fires shall be extinguished with a gentle application of water fog onto the bearing for cooling.

10.5.2.12.2 If water is not available, other means of extinguishment shall be permitted to be used on the bearing fire, provided caution is taken to avoid the suspension of combustible dust.

10.5.2.12.3 If the bearing is located inside equipment, material flow shall be stopped, equipment shall be shut down, and extreme caution shall be used when equipment is opened.

10.6 Agricultural and Food Processing

10.7 Combustible Metals

10.7.1 Local emergency response agency notification shall be required for any operation storing or processing 5 lb (2.27 kg) or more of powder, dusts, fines, or alkali metal in any form or 500 lb (227 kg) or more of chips or turnings.

10.7.2 The following list of actions to be performed as well as information regarding the hazards of combustible metals shall be provided to emergency responders for the safe handling of combustible metal fires:

10.7.2.1 Perform a size-up, evaluation, and identification of metals involved in the fire.

10.7.2.2 Ensure control of utilities (e.g., water, gases, power, etc.) to affected areas.

10.7.2.3 Review safety data sheets (SDSs) for the involved products, and if available, contact those familiar with the product and hazards.

10.7.2.4 Evaluate whether the fire can be isolated safely and allowed to burn out.

10.7.2.5 Determine whether uninvolved product and exposures — other than alkali metals — can be protected by hose streams, after an adequate review has been completed to ensure any runoff from hose streams does not come into contact with burning or molten combustible metal.

10.7.2.6 Do not apply water to alkali metals in either a fire or non-fire situation.

10.7.2.7 Use an inert blanket, such as argon, helium, or nitrogen, if the fire is burning in a closed container, such as a dust collection system, to control the fire

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

where an adequate delivery system is available and personnel safety is considered.

10.7.2.8 Evaluate the potential for explosion.

10.7.2.9 Use extreme caution with fires involving combustible-metal powders, dusts, and fines because of the possibility of explosions, especially if the product becomes airborne and there is an available ignition source.

10.7.2.10 Evaluate whether there is adequate drainage to prevent the contact of water with burning metal that is not compatible for protecting exposures.

10.7.2.11 Evaluate the fire to determine whether the fire can burn itself out naturally to minimize hazards to personnel and losses to exposures.

10.7.2.12 Evaluate the control and shutdown of both domestic and fire protection water systems to prevent unintended contact of water with burning or molten combustible metal.

10.7.2.13 Use extinguishing agents that are compatible with the hazards present.

10.7.2.14 Use extinguishing agents for containment of small and incipient fires.

10.7.2.15 Use extreme caution with fires involving large quantities of product within structures.

10.7.2.16 Most fires involving combustible metals cannot be extinguished in a manner other than by providing an inert atmosphere of argon or helium — and nitrogen for alkali metals or iron — if the product is dry.

10.7.2.17 Most fires can be controlled by application of argon or helium — or nitrogen for alkali metals or iron— or by the development of an oxide crust.

10.7.2.18 The temperature of the metals involved in the fire can remain extremely high and the fire can flare up again if the product is disturbed prior to complete oxidation of the product or self-extinguishment.

10.7.2.19 Water in contact with molten combustible metals will result in violent steam explosions, and can cause hydrogen explosions and reactions.

10.7.2.20 Isolate the metal as much as possible; large fires might be impossible to extinguish.

10.7.2.21 The physical state of the product, such as chips, powder, fines, and dust, and the quantity of product involved in the fire, potentially involved in the fire, or both, are extremely important factors for emergency responders.

10.7.2.22 Fires involving large quantities of product within structures can result in rapid heat buildup and smoke generation beyond that normally encountered in fires involving ordinary combustibles.

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

10.7.3 Firefighting Activities.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.7.3.1 Trained employees shall be permitted to fight incipient-stage fires, provided the fire can be controlled with portable extinguishers or other dry extinguishing agent.

10.7.3.2 In case of fire in reactive metal chips, turnings, or powder compact, the pan or tray shall not be disturbed or moved, except by an individual knowledgeable in the fire aspects of combustible metals, until the fire has been extinguished and the material has cooled to ambient temperature.

10.7.3.3 Combustible-metal fires beyond the incipient stage shall be fought by professional firefighters, specially trained fire brigade personnel, or both.

10.7.3.4 Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residue has cooled to room temperature.

10.7.3.5 Fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

10.7.3.6 Burning combustible metals will burn through material used in the construction of most firefighter protective clothing. Some features (e.g., heavy quilted linings, aluminized outer shells) can reduce this risk. The self-contained breathing apparatus (SCBA) facepiece eye protection worn by firefighters adequately protects against the effects of a lithium fire, with the exception of the intense light given off by burning lithium. *(See NFPA 1500.)*

10.7.3.7 Specific testing indicates that white-light levels emitted from burning lithium exceed recommended levels, and extended lithium fire experience has shown that this intense light can cause serious damage to unprotected eyes. A clip-on adapter over an SCBA facepiece with a shaded glass lens equivalent to a No. 6 welding lens has been used successfully to reduce such hazards. A darker lens tends to obstruct the firefighter's view to an unacceptable degree.

10.7.3.8 Fire residues shall be disposed of in accordance with federal, state, and local regulations.

10.7.3.9 When drums or tote bins of burning materials can be moved safely, they shall be moved away from processing equipment and out of buildings as rapidly as possible.

10.7.4 Alkali Metals Firefighting Procedures.

10.7.4.1 While an alkali-metal fire is being fought, every effort shall be made to avoid splattering the burning alkali metals.

10.7.4.2 Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residues have cooled to room temperature.

10.7.5 Firefighting Organization.

10.7.5.1 Only trained personnel shall be permitted to engage in fire control activity.

10.7.5.2 Personnel other than trained personnel shall be evacuated from the area.

10.7.5.3 Training shall emphasize the different types of fires anticipated and the appropriate agents and techniques to be used.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.7.5.4 Firefighting personnel shall be given training in the extinguishment of test fires set in a safe location away from manufacturing buildings.

10.7.5.5 Training shall include all possible contingencies.

10.7.5.6 If professional or volunteer firefighters are admitted onto the property in the event of a fire emergency, their activity shall be directed by a unified incident command that includes knowledgeable plant personnel.

10.7.5.7 The following information on the safe handling of combustible metal fires shall be provided for emergency preparedness planning:

10.7.5.8 Water, when applied to most burning combustible metals, results in an increase in burning intensity and possible explosion.

10.7.5.9 Water applied to alkali metals not involved in the fire will result in hazardous decomposition, ignition, or explosion.

10.7.5.10 Application of carbon dioxide on combustible-metal fire adds to the intensity of the burning. Most combustible metals ignite and burn in 100 percent carbon dioxide atmospheres.

10.7.5.11 Dry chemical extinguishers react with alkali metals and intensify the fire.

10.7.5.12 Dry chemical extinguishers utilized on non-alkali metal fires are ineffective in controlling the metal fire but might be effective where ignitable (flammable or combustible) liquids are used and the metal is not yet involved in the fire.

10.7.5.13 Halogenated extinguishing agents used on alkali metals can result in an explosion.

10.7.5.14 Halogenated extinguishing agents will have a detrimental effect on other combustible metal fires, with the decomposition producing hazardous by-products.

10.7.5.15 A primary metal fire displays intense orange-to-white flame and can be associated with a heavy or large production of white or gray smoke.

10.7.5.16 When water is applied to non-alkali combustible metal, it can disassociate to the basic compounds, oxygen and hydrogen. Similar results occur with carbon dioxide.

10.7.5.17 When water is applied to alkali metals, hydroxides and hydrogen are generated immediately.

10.7.5.18 Fires involving combustible metals that contain moisture exhibit more intense burning characteristics than dry product.

10.7.5.19 Extreme heat can be produced. For example, burning titanium and zirconium have the potential to produce temperatures in excess of 7000°F (3857°C) and 8500°F (4690°C), respectively.

10.7.5.20 Dusts, fines, and powders of combustible metals present an explosion hazard, especially in confined spaces.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.7.5.21 Dusts, fines, and powders of titanium and zirconium present extreme hazards; zirconium powders have ignition temperatures as low as 68°F (20°C). Static electric charges can ignite some dusts and powders of titanium and zirconium.

10.7.5.22 Zirconium and titanium powder can exhibit pyrophoric characteristics.

10.7.5.23 Turnings and chips of combustible metals can ignite and burn with intensity, especially if coated with a petroleum-based oil, with some spontaneous combustion having been observed.

10.7.5.24 With the exception of alkali metals, the larger the product, the smaller the likelihood of ignition. Bars, ingots, heavy castings, and thick plates and sheets are virtually impossible to ignite and, in most cases, self-extinguish when the heat source is removed.

10.7.5.25 The sponge product of most combustible metals burns at a slower rate but still produces tremendous heat.

10.7.5.26 Burning combustible metals can extract moisture from concrete and similar products that can intensify burning and cause spalling and explosion of the products and spewing of chunks of concrete.

10.7.5.27 Burning metal destroys asphalt and extracts moisture from rock which may explode spewing rock fragments.

10.7.5.28 Most fires involving non-alkali combustible metals usually cannot be extinguished, and unless they are placed in an inert atmosphere of argon or helium, they can only be controlled.

10.7.5.29 Fires involving large quantities of metals shall be allowed to cool for at least 24 hours prior to being disturbed to prevent re-ignition.

10.7.5.30 Fires will oxidize most metals and provide a protective covering limiting open burning.

10.7.5.31 Alkali metal fires can be extinguished with the suitable extinguishing agents correctly applied.

10.7.5.32 Combustible metal fines and powders that are stored and contain moisture can produce hydrogen gas.

10.7.5.33 Combustible metal fines and dusts that are reduced (not oxidized) and that come into contact with other metal oxides can result in thermite reactions.

10.7.5.34 Prior to the arrival of alkali metals on site, the local fire department shall be notified of the presence of water-reactive materials on site and shall be notified of the hazards of using water on alkali-metal fires.

10.8 Sulfur

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

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.8.1.1 Inert gas system in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

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

10.8.1.3 Rapid sealing of the enclosure to exclude air

10.8.2 Snuffing Steam and Sealing Steam Precautions.

10.8.3 The vent systems on enclosed sulfur tanks and sulfur pits shall be designed to allow the required snuffing steam rate or sealing steam rate to vent without overpressuring the enclosure.

10.8.3.1 The vent systems shall also be designed for proper operation during normal operation.

10.8.4 Water Extinguishing Precautions.

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

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

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

10.8.5 Dry Chemical Extinguishers.

10.8.5.1 Where sulfur is being heated by a combustible heat transfer fluid, dry chemical extinguishers complying with NFPA 17 shall be provided.

10.8.6 It shall be permitted to use straight stream nozzles or combination nozzles to reach fires in locations that are otherwise inaccessible.

10.9 Wood Processing and Woodworking Facilities

10.10 Combustible Dusts and Particulate Solids Not Otherwise Specified

Annex:

A.10.2.1

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

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

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 firefighting. *(See OSHA's publication, Firefighting Precautions at Facilities with Combustible Dust, for additional information.)*

A.10.3.10 *See OSHA's publication, Firefighting Precautions at Facilities with Combustible Dust, for additional information.*

A.10.4.1 This plan should meet the recommendations contained in the *National Grain and Feed Association Research Report, Emergency Preplanning and Fire Fighting Manual - A Guide for Grain Elevator Operators and Fire Department Officials* or other industry or commodity specific guide.

A.10.4.2.1
Burning combustible metals will burn through material used in the construction of most firefighter protective clothing. Some features (e.g., heavy quilted linings, aluminized outer shells) can reduce this risk. The self-contained breathing apparatus (SCBA) facepiece eye protection worn by firefighters adequately protects against the effects of a lithium fire, with the exception of the intense light given off by burning lithium. *(See NFPA 1500.)*
Specific testing indicates that white-light levels emitted from burning lithium exceed recommended levels, and extended lithium fire experience has shown that this intense light can cause serious damage to unprotected eyes. A clip-on adapter over an SCBA facepiece with a shaded glass lens equivalent to a No. 6 welding lens has been used successfully to reduce such hazards. A darker lens tends to obstruct the firefighter's view to an unacceptable degree.

A.10.4.3 Manual firefighting could pose an unacceptable risk to facility personnel and emergency responders.

A.10.4.5.4 A nozzle listed or approved for use on Class C fires produces a fog discharge pattern that is less likely than a straight stream nozzle to suspend combustible dust, which could otherwise produce a dust flash fire or explosion potential.

A.10.5.2.4 *Elevator Leg Fires.* Material flow into a leg should be stopped and the leg should be shut down. Leg fires should be extinguished by water fog or gentle application of water. Fires

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

should be located by feeling the leg casing for heat or observing discoloration of metal. If the location is unknown, water should be applied first in the boot section, then in the bin-pulley access door, and last in the head section.

A.10.5.2.5 *Conveyor Belt Fires.* The conveyor belt should be shutdown (halted). Conveyor belt fires should be extinguished by application of water. Material flow to the conveyor belt should be stopped. If necessary, the belt should be cut to isolate the fire.

A.10.5.2.6 *Dryer Fires.* Dryer fires should be extinguished by removing burning material from the dryer or gentle application of water. Fuel to burners, fans, and material flow into the dryer and from the facility should be stopped. If necessary, emergency dump should be used to remove material from the dryer.

A.10.5.2.7 *Concrete Bin or Silo and Steel Tank Fires.* Concrete bin or silo fires should be extinguished by wetting the top surface of the material with gentle application of water at a low flow rate directly to the burning materials, and then removal of burning material from the bin or silo directly to the outside. Fire should be located by thermometer probes, thermographic photography, or feeling heat on bin or silo surfaces. Openings to the bin or silo should be sealed to limit oxygen entry. Material flow to and from the bin or silo should be stopped. Firefighting operations should be done from outside the bin or silo. Fires should be isolated by selective unloading of material onto the ground.

A.10.5.2.8 *Concrete Bin or Silo and Steel Tank Smolders.* A deep-seated smolder in a bin, tank, or silo should not be extinguished with water. The addition of water can generate CO that would build up in the bin and potentially explode [see list item (7)]. A better approach is to inject inert gas (such as carbon dioxide or nitrogen) to displace the oxygen and smother the smolder.

A.10.5.2.9 *Fumigant or Chemical Fires.* Fires involving fumigants containing phosphine should be extinguished by inert material or nonaqueous agent used for Class B fires. Water should not be used for phosphine fires to avoid exothermic reaction and development of explosive gases.

A10.5.2.10 *Water Gas Reaction.* Application of small amounts of water on glowing grain in a partially confined space, such as a grain silo, and in the presence of air can generate a water gas reaction. The glowing grain must be at a temperature of at least 1290°F to 1470°F (700°C to 800°C), and initial water contact might not cool the mass of glowing grain below 1110°F (600°C). The partial oxidation reduction between carbon and water forms carbon monoxide and hydrogen as shown in Equation A.11.5.2.10.

$$C + H_2O \rightarrow CO + H_2$$ **[A.11.5.2.10a]**

In the presence of oxygen (air), the carbon monoxide and hydrogen burn, immediately releasing heat as shown in Equation A.11.8.10.3b.

$$C + H_2O + O_2 \rightarrow CO_2 + H_2O + 19{,}440\ \text{J/g}\ (8350\ \text{Btu/lb})$$ **[A.11.5.2.b]**

In a partially confined space, the combustion energy will rapidly pressurize the space beyond what the silo walls or tops can withstand, causing destruction of the silo.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

A.10.7 The objectives in fighting combustible metal fires are isolation and containment, rather than extinguishment. Water and other liquids have proved ineffective in extinguishing combustible metal fires. Streams of water intensify most combustible metal fires by feeding it oxygen. There is also the possibility of causing a steam or hydrogen explosion, particularly if large amounts of combustible metal are involved. The great affinity of high-temperature combustible metal for oxygen frees a considerable amount of hydrogen, which can reach explosive concentrations in confined spaces. Entrapment of water under any burning or hot combustible metal can result in a steam explosion.

Because of their unique nature, combustible metal fires demand a comprehensive fire protection plan wherever combustible metal is processed, handled, used, or stored. This plan should include specific actions in the event of a combustible metal fire and should be coordinated with the local facility management, responding firefighters, and medical personnel.

The plan should recognize the extreme hazards associated with combustible metal–water reactions that might occur with sprinkler water. Specific attention should be given to an evacuation plan for personnel in the event of any release of water.

Properly trained personnel who work with combustible metal know its hazards. Such personnel are best equipped to extinguish a combustible metal fire in its incipient stage. Training should include sufficient information to determine whether extinguishment can be accomplished safely and effectively.

A.10.7.3.1 One of the greatest dangers to firefighters is the splattering effect of burning alkali metals. Molten alkali metal is very fluid and easily spread; therefore, extreme care needs to be taken when applying firefighting agent. The force used to deliver agent from an extinguisher can cause the molten alkali to splash to adjacent areas. Therefore, the delivery technique is very important. If direct agent application becomes hazardous, indirect application techniques should be used. Deflecting agent off another object or directing the agent stream above the hazard and letting the agent fall by gravity can be effective.

A.10.7.3.2 Forming a crust over burning alkali metals reduces the available oxygen and eliminates exothermic reactions. Extinguishing agent should first be applied to the white-hot burning areas, then evenly applied to the mass, controlling the flow to form an oxygen-depleting crust. Since alkali metal tends to flow easily through any weak spots, agents should be applied evenly to construct a continuous crust. If the alkali metal surfaces, additional agent should be applied to strengthen the crust.

Actual crust formation is created by the ability of some powdered agents to absorb heat from the alkali metals. In the case of copper powder, an alkali metal–copper alloy is formed as heat is absorbed from an alkali metal. Once the crust is formed, the temperature of the alkali metal decreases and exothermic reactions are reduced. Extreme care should be taken to ensure that the crust is not disturbed or broken until the temperature of the alkali metal is decreased to the point where resolidification occurs (or in the case of NaK, until the mass is at or near room temperature).

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

A.10.7.4.6 It is recommended that a practice fire drill be conducted once each year to familiarize local fire department personnel with the proper methods of fighting Class D fires. Professional or volunteer firefighters from outside the plant cannot be expected to be trained for the specific fire and life hazards associated with metal powder and fires. In the interest of their own safety, they should be directed by the plant's safety officer or firefighting officer.

Public Input No. 175-NFPA 660-2026 [Chapter 10 [Title Only]]

Emergency Planning and ~~Response~~ Manual Firefighting

Additional Proposed Changes

File Name	Description	Approved
NFPA_660_Firefighting_Task_Group_01042024_-_revisions.1704401149681.docx	Revised Chapter 10 from task group during last cycle	

Statement of Problem and Substantiation for Public Input

This chapter provides more comprehensive guidance about Emergency Planning and Manual fire fighting for all industries and committees handling combustible dust. This was developed by a task group during the last cycle.

Submitter Information Verification

Submitter Full Name: Timothy Myers
Organization: Exponent, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jan 07 14:00:47 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: FR-31-NFPA 660-2026
Statement: The requirements throughout NFPA 660 pertaining to emergency planning and response have been consolidated into Chapter 10. The Technical Committee on Fundamentals of Combustible Dust asks the other Technical Committees to consider removing duplicative requirements from the other chapters.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.1 Retroactivity

This chapter and the corresponding X.10 sections of the industry- and commodity-specific chapters shall be applied retroactively to new and existing facilities and processes.

10.2 Emergency Planning & Response

10.2.1 A written emergency response plan shall be developed for preparing for and responding to work-related emergencies including, but not limited to, fires, flash fires, and explosions.

10.2.2 Emergency planning and response shall be in accordance with NFPA 600, *Standard on Facility Fire Brigades* (if applicable), and NFPA 1660, *Standard on Continuity, Emergency, and Crisis Management*.

10.2.3 The emergency response plan shall include, but not be limited to, the following:

10.2.3.1 A means of notification for occupants in the event of fire and explosion

10.2.3.2 A preplanned evacuation assembly area

10.2.3.3 A person(s) designated to notify emergency responders, including the fire department

10.2.3.4 A facility layout drawing(s) showing egress routes, hazardous chemical locations, and fire protection equipment

10.2.3.5 Location of a safety data sheet(s) for hazardous chemicals

10.2.3.6 Plant management emergency telephone number(s)

10.2.3.7 Emergency response duties for occupants

10.2.3.8 A person(s) designated to meet the offsite emergency responder(s) to coordinate the incident

10.2.3.9 Interdepartmental and interplant cooperation

10.2.3.10 Cooperation of outside agencies

10.2.3.11 The release of accurate information to the public

10.2.4 The emergency response plan shall address locations for remote shutoff of supply systems when any of the following are present:

10.2.4.1 Water (water from all types of sources)

10.2.4.2 Electrical materials

10.2.4.3 Flammable gases

10.2.4.4 Ignitable (flammable or combustible) liquids

10.2.4.5 Toxic materials

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.2.4.6 Other hazardous materials

10.3 Emergency Response Plan and Training

10.3.1 Employee health and safety in operations shall depend on the recognition of actual or potential hazards, the control or elimination of those hazards, and the training of employees on safe working procedures.

10.3.2 The emergency response plan shall be available on-site or electronically.

10.3.3 Fires, when discovered, shall be reported promptly to facility management and emergency responders, including the fire department.

10.3.4 If a fire cannot be controlled promptly in its incipient stage, the endangered structure(s) shall be evacuated.

10.3.5 Emergency drills shall be performed annually by plant personnel and validated as required by process changes.

10.3.6 Plant personnel, including management, supervisors, and maintenance and operating personnel, shall be trained to participate in plans for controlling plant emergencies.

10.3.7 The emergency response plan shall be shared with relevant local community officials and emergency response agencies.

10.3.8 Malfunctions of the process shall be simulated and emergency actions undertaken as necessary.

10.3.9 Disaster drills that simulate a major catastrophic situation shall be undertaken periodically with the cooperation and participation of public fire, police, and other local community emergency units and nearby cooperating plants.

10.3.10 Specialized training for the public fire department(s) and industrial fire brigades shall be warranted when the facility-specific hazards dictate that the methods to control and extinguish a fire are outside of their normal arena of traditional firefighting.

10.4 Manual Firefighting

10.4.1 Those individuals responsible for manual fire suppression shall have a fire protection plan.

10.4.2 Proper protective clothing, respiratory protection, and adequate eye protection shall be used by all responding firefighting personnel assigned to a combustible metal fire equipped to the requirements of NFPA 600, *Standard on Facility Fire Brigades* (if applicable) or NFPA 1081, *Standard for Facility Fire Brigade Member Professional Qualifications*.

10.4.3 The evaluation of the risk to facility personnel and firefighters shall be made based on discussions with the responding fire department(s) and review of the DHA.

10.4.4 The potential effectiveness of manual firefighting shall be assessed by experienced firefighting personnel after reviewing the hazard assessment documentation developed in accordance with the DHA.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.4.5 For materials that can be effectively extinguished with water, hose streams shall be used with great care to avoid creating dust clouds or causing structural damage to bins.

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

10.4.5.2 Fire responders shall be cautioned when using straight stream nozzles in the vicinity of combustible dust accumulations that dust clouds can be formed and can be ignited by any residual smoldering or fire.

10.4.5.3 Straight stream nozzles or combination nozzles shall be permitted to be used to reach fires in locations that are otherwise inaccessible with the nozzles specified in 11.8.10.3.5.

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

10.4.6 Where firefighting water or wet product can accumulate in the system, the vessel, pipe supports, and drains shall be designed to support the additional water weight in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists and Particulate Solids*.

10.5 Firefighting Operations / Activities

10.5.1 Incipient firefighting techniques shall be established for fighting different types of fires that may be present at a facility including:

10.5.2 Clothing Fires.

10.5.2.1 Emergency procedures for handling clothing fires shall be established as part of the plan.

10.5.2.2 If deluge showers are installed, they shall be located away from dry metal powder–processing and metal powder–handling areas if water is not an effective extinguishing agent.

10.5.2.3 The plan shall address locations for remote shutoff of supply systems when any of the following are present:

- Water (water from all types of sources)
- Electrical materials
- Flammable gases
- Ignitible (flammable or combustible) liquids
- Toxic materials
- Other hazardous materials

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.5.2.4 In plant areas where water is excluded, fire blankets shall be distributed for extinguishing clothing fires.

10.5.2.5 Elevator leg fires

10.5.2.5.1 Burning material shall not be transferred into legs.

10.5.2.6 Conveyor belt fires

10.5.2.7 Dryer fires

10.5.2.8 Concrete bin or silo and steel tank fires

10.5.2.9 Concrete Bin or Silo and Steel Tank Smolders

10.5.2.10 Fumigant or Chemical Fires

10.5.2.11 Water Gas Reaction

10.5.2.12 Bearing Fires

10.5.2.12.1 Bearing fires shall be extinguished with a gentle application of water fog onto the bearing for cooling.

10.5.2.12.2 If water is not available, other means of extinguishment shall be permitted to be used on the bearing fire, provided caution is taken to avoid the suspension of combustible dust.

10.5.2.12.3 If the bearing is located inside equipment, material flow shall be stopped, equipment shall be shut down, and extreme caution shall be used when equipment is opened.

10.6 Agricultural and Food Processing

10.7 Combustible Metals

10.7.1 Local emergency response agency notification shall be required for any operation storing or processing 5 lb (2.27 kg) or more of powder, dusts, fines, or alkali metal in any form or 500 lb (227 kg) or more of chips or turnings.

10.7.2 The following list of actions to be performed as well as information regarding the hazards of combustible metals shall be provided to emergency responders for the safe handling of combustible metal fires:

10.7.2.1 Perform a size-up, evaluation, and identification of metals involved in the fire.

10.7.2.2 Ensure control of utilities (e.g., water, gases, power, etc.) to affected areas.

10.7.2.3 Review safety data sheets (SDSs) for the involved products, and if available, contact those familiar with the product and hazards.

10.7.2.4 Evaluate whether the fire can be isolated safely and allowed to burn out.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.7.2.5 Determine whether uninvolved product and exposures — other than alkali metals — can be protected by hose streams, after an adequate review has been completed to ensure any runoff from hose streams does not come into contact with burning or molten combustible metal.

10.7.2.6 Do not apply water to alkali metals in either a fire or non-fire situation.

10.7.2.7 Use an inert blanket, such as argon, helium, or nitrogen, if the fire is burning in a closed container, such as a dust collection system, to control the fire where an adequate delivery system is available and personnel safety is considered.

10.7.2.8 Evaluate the potential for explosion.

10.7.2.9 Use extreme caution with fires involving combustible-metal powders, dusts, and fines because of the possibility of explosions, especially if the product becomes airborne and there is an available ignition source.

10.7.2.10 Evaluate whether there is adequate drainage to prevent the contact of water with burning metal that is not compatible for protecting exposures.

10.7.2.11 Evaluate the fire to determine whether the fire can burn itself out naturally to minimize hazards to personnel and losses to exposures.

10.7.2.12 Evaluate the control and shutdown of both domestic and fire protection water systems to prevent unintended contact of water with burning or molten combustible metal.

10.7.2.13 Use extinguishing agents that are compatible with the hazards present.

10.7.2.14 Use extinguishing agents for containment of small and incipient fires.

10.7.2.15 Use extreme caution with fires involving large quantities of product within structures.

10.7.2.16 Most fires involving combustible metals cannot be extinguished in a manner other than by providing an inert atmosphere of argon or helium — and nitrogen for alkali metals or iron — if the product is dry.

10.7.2.17 Most fires can be controlled by application of argon or helium — or nitrogen for alkali metals or iron— or by the development of an oxide crust.

10.7.2.18 The temperature of the metals involved in the fire can remain extremely high and the fire can flare up again if the product is disturbed prior to complete oxidation of the product or self-extinguishment.

10.7.2.19 Water in contact with molten combustible metals will result in violent steam explosions, and can cause hydrogen explosions and reactions.

10.7.2.20 Isolate the metal as much as possible; large fires might be impossible to extinguish.

10.7.2.21 The physical state of the product, such as chips, powder, fines, and dust, and the quantity of product involved in the fire, potentially involved in the fire, or both, are extremely important factors for emergency responders.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.7.2.22 Fires involving large quantities of product within structures can result in rapid heat buildup and smoke generation beyond that normally encountered in fires involving ordinary combustibles.

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

10.7.3 Firefighting Activities.

10.7.3.1 Trained employees shall be permitted to fight incipient-stage fires, provided the fire can be controlled with portable extinguishers or other dry extinguishing agent.

10.7.3.2 In case of fire in reactive metal chips, turnings, or powder compact, the pan or tray shall not be disturbed or moved, except by an individual knowledgeable in the fire aspects of combustible metals, until the fire has been extinguished and the material has cooled to ambient temperature.

10.7.3.3 Combustible-metal fires beyond the incipient stage shall be fought by professional firefighters, specially trained fire brigade personnel, or both.

10.7.3.4 Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residue has cooled to room temperature.

10.7.3.5 Fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

10.7.3.6 Burning combustible metals will burn through material used in the construction of most firefighter protective clothing. Some features (e.g., heavy quilted linings, aluminized outer shells) can reduce this risk. The self-contained breathing apparatus (SCBA) facepiece eye protection worn by firefighters adequately protects against the effects of a lithium fire, with the exception of the intense light given off by burning lithium. *(See NFPA 1500.)*

10.7.3.7 Specific testing indicates that white-light levels emitted from burning lithium exceed recommended levels, and extended lithium fire experience has shown that this intense light can cause serious damage to unprotected eyes. A clip-on adapter over an SCBA facepiece with a shaded glass lens equivalent to a No. 6 welding lens has been used successfully to reduce such hazards. A darker lens tends to obstruct the firefighter's view to an unacceptable degree.

10.7.3.8 Fire residues shall be disposed of in accordance with federal, state, and local regulations.

10.7.3.9 When drums or tote bins of burning materials can be moved safely, they shall be moved away from processing equipment and out of buildings as rapidly as possible.

10.7.4 Alkali Metals Firefighting Procedures.

10.7.4.1 While an alkali-metal fire is being fought, every effort shall be made to avoid splattering the burning alkali metals.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.7.4.2 Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residues have cooled to room temperature.

10.7.5 Firefighting Organization.

10.7.5.1 Only trained personnel shall be permitted to engage in fire control activity.

10.7.5.2 Personnel other than trained personnel shall be evacuated from the area.

10.7.5.3 Training shall emphasize the different types of fires anticipated and the appropriate agents and techniques to be used.

10.7.5.4 Firefighting personnel shall be given training in the extinguishment of test fires set in a safe location away from manufacturing buildings.

10.7.5.5 Training shall include all possible contingencies.

10.7.5.6 If professional or volunteer firefighters are admitted onto the property in the event of a fire emergency, their activity shall be directed by a unified incident command that includes knowledgeable plant personnel.

10.7.5.7 The following information on the safe handling of combustible metal fires shall be provided for emergency preparedness planning:

10.7.5.8 Water, when applied to most burning combustible metals, results in an increase in burning intensity and possible explosion.

10.7.5.9 Water applied to alkali metals not involved in the fire will result in hazardous decomposition, ignition, or explosion.

10.7.5.10 Application of carbon dioxide on combustible-metal fire adds to the intensity of the burning. Most combustible metals ignite and burn in 100 percent carbon dioxide atmospheres.

10.7.5.11 Dry chemical extinguishers react with alkali metals and intensify the fire.

10.7.5.12 Dry chemical extinguishers utilized on non-alkali metal fires are ineffective in controlling the metal fire but might be effective where ignitable (flammable or combustible) liquids are used and the metal is not yet involved in the fire.

10.7.5.13 Halogenated extinguishing agents used on alkali metals can result in an explosion.

10.7.5.14 Halogenated extinguishing agents will have a detrimental effect on other combustible metal fires, with the decomposition producing hazardous by-products.

10.7.5.15 A primary metal fire displays intense orange-to-white flame and can be associated with a heavy or large production of white or gray smoke.

10.7.5.16 When water is applied to non-alkali combustible metal, it can disassociate to the basic compounds, oxygen and hydrogen. Similar results occur with carbon dioxide.

10.7.5.17 When water is applied to alkali metals, hydroxides and hydrogen are generated immediately.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.7.5.18 Fires involving combustible metals that contain moisture exhibit more intense burning characteristics than dry product.

10.7.5.19 Extreme heat can be produced. For example, burning titanium and zirconium have the potential to produce temperatures in excess of 7000°F (3857°C) and 8500°F (4690°C), respectively.

10.7.5.20 Dusts, fines, and powders of combustible metals present an explosion hazard, especially in confined spaces.

10.7.5.21 Dusts, fines, and powders of titanium and zirconium present extreme hazards; zirconium powders have ignition temperatures as low as 68°F (20°C). Static electric charges can ignite some dusts and powders of titanium and zirconium.

10.7.5.22 Zirconium and titanium powder can exhibit pyrophoric characteristics.

10.7.5.23 Turnings and chips of combustible metals can ignite and burn with intensity, especially if coated with a petroleum-based oil, with some spontaneous combustion having been observed.

10.7.5.24 With the exception of alkali metals, the larger the product, the smaller the likelihood of ignition. Bars, ingots, heavy castings, and thick plates and sheets are virtually impossible to ignite and, in most cases, self-extinguish when the heat source is removed.

10.7.5.25 The sponge product of most combustible metals burns at a slower rate but still produces tremendous heat.

10.7.5.26 Burning combustible metals can extract moisture from concrete and similar products that can intensify burning and cause spalling and explosion of the products and spewing of chunks of concrete.

10.7.5.27 Burning metal destroys asphalt and extracts moisture from rock which may explode spewing rock fragments.

10.7.5.28 Most fires involving non-alkali combustible metals usually cannot be extinguished, and unless they are placed in an inert atmosphere of argon or helium, they can only be controlled.

10.7.5.29 Fires involving large quantities of metals shall be allowed to cool for at least 24 hours prior to being disturbed to prevent re-ignition.

10.7.5.30 Fires will oxidize most metals and provide a protective covering limiting open burning.

10.7.5.31 Alkali metal fires can be extinguished with the suitable extinguishing agents correctly applied.

10.7.5.32 Combustible metal fines and powders that are stored and contain moisture can produce hydrogen gas.

10.7.5.33 Combustible metal fines and dusts that are reduced (not oxidized) and that come into contact with other metal oxides can result in thermite reactions.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

10.7.5.34 Prior to the arrival of alkali metals on site, the local fire department shall be notified of the presence of water-reactive materials on site and shall be notified of the hazards of using water on alkali-metal fires.

10.8 Sulfur

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

10.8.1.1 Inert gas system in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

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

10.8.1.3 Rapid sealing of the enclosure to exclude air

10.8.2 Snuffing Steam and Sealing Steam Precautions.

10.8.3 The vent systems on enclosed sulfur tanks and sulfur pits shall be designed to allow the required snuffing steam rate or sealing steam rate to vent without overpressuring the enclosure.

10.8.3.1 The vent systems shall also be designed for proper operation during normal operation.

10.8.4 Water Extinguishing Precautions.

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

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

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

10.8.5 Dry Chemical Extinguishers.

10.8.5.1 Where sulfur is being heated by a combustible heat transfer fluid, dry chemical extinguishers complying with NFPA 17 shall be provided.

10.8.6 It shall be permitted to use straight stream nozzles or combination nozzles to reach fires in locations that are otherwise inaccessible.

10.9 Wood Processing and Woodworking Facilities

10.10 Combustible Dusts and Particulate Solids Not Otherwise Specified

Annex:

A.10.2.1

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:

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

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 firefighting. *(See OSHA's publication, Firefighting Precautions at Facilities with Combustible Dust, for additional information.)*

A.10.3.10 *See OSHA's publication, Firefighting Precautions at Facilities with Combustible Dust, for additional information.*

A.10.4.1 This plan should meet the recommendations contained in the *National Grain and Feed Association Research Report, Emergency Preplanning and Fire Fighting Manual - A Guide for Grain Elevator Operators and Fire Department Officials* or other industry or commodity specific guide.

A.10.4.2.1
Burning combustible metals will burn through material used in the construction of most firefighter protective clothing. Some features (e.g., heavy quilted linings, aluminized outer shells) can reduce this risk. The self-contained breathing apparatus (SCBA) facepiece eye protection worn by firefighters adequately protects against the effects of a lithium fire, with the exception of the intense light given off by burning lithium. *(See NFPA 1500.)*
Specific testing indicates that white-light levels emitted from burning lithium exceed recommended levels, and extended lithium fire experience has shown that this intense light can cause serious damage to unprotected eyes. A clip-on adapter over an SCBA facepiece with a shaded glass lens equivalent to a No. 6 welding lens has been used successfully to reduce such hazards. A darker lens tends to obstruct the firefighter's view to an unacceptable degree.

A.10.4.3 Manual firefighting could pose an unacceptable risk to facility personnel and emergency responders.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

A.10.4.5.4 A nozzle listed or approved for use on Class C fires produces a fog discharge pattern that is less likely than a straight stream nozzle to suspend combustible dust, which could otherwise produce a dust flash fire or explosion potential.

A.10.5.2.4 *Elevator Leg Fires.* Material flow into a leg should be stopped and the leg should be shut down. Leg fires should be extinguished by water fog or gentle application of water. Fires should be located by feeling the leg casing for heat or observing discoloration of metal. If the location is unknown, water should be applied first in the boot section, then in the bin-pulley access door, and last in the head section.

A.10.5.2.5 *Conveyor Belt Fires.* The conveyor belt should be shutdown (halted). Conveyor belt fires should be extinguished by application of water. Material flow to the conveyor belt should be stopped. If necessary, the belt should be cut to isolate the fire.

A.10.5.2.6 *Dryer Fires.* Dryer fires should be extinguished by removing burning material from the dryer or gentle application of water. Fuel to burners, fans, and material flow into the dryer and from the facility should be stopped. If necessary, emergency dump should be used to remove material from the dryer.

A.10.5.2.7 *Concrete Bin or Silo and Steel Tank Fires.* Concrete bin or silo fires should be extinguished by wetting the top surface of the material with gentle application of water at a low flow rate directly to the burning materials, and then removal of burning material from the bin or silo directly to the outside. Fire should be located by thermometer probes, thermographic photography, or feeling heat on bin or silo surfaces. Openings to the bin or silo should be sealed to limit oxygen entry. Material flow to and from the bin or silo should be stopped. Firefighting operations should be done from outside the bin or silo. Fires should be isolated by selective unloading of material onto the ground.

A.10.5.2.8 *Concrete Bin or Silo and Steel Tank Smolders.* A deep-seated smolder in a bin, tank, or silo should not be extinguished with water. The addition of water can generate CO that would build up in the bin and potentially explode [see list item (7)]. A better approach is to inject inert gas (such as carbon dioxide or nitrogen) to displace the oxygen and smother the smolder.

A.10.5.2.9 *Fumigant or Chemical Fires.* Fires involving fumigants containing phosphine should be extinguished by inert material or nonaqueous agent used for Class B fires. Water should not be used for phosphine fires to avoid exothermic reaction and development of explosive gases.

A10.5.2.10 *Water Gas Reaction.* Application of small amounts of water on glowing grain in a partially confined space, such as a grain silo, and in the presence of air can generate a water gas reaction. The glowing grain must be at a temperature of at least 1290°F to 1470°F (700°C to 800°C), and initial water contact might not cool the mass of glowing grain below 1110°F (600°C). The partial oxidation reduction between carbon and water forms carbon monoxide and hydrogen as shown in Equation A.11.5.2.10.

$$C + H_2O \rightarrow CO + H_2 \qquad \textbf{[A.11.5.2.10a]}$$

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

In the presence of oxygen (air), the carbon monoxide and hydrogen burn, immediately releasing heat as shown in Equation A.11.8.10.3b.

$$C + H_2O + O_2 \rightarrow CO_2 + H_2O + 19{,}440\ \text{J/g}\ (8350\ \text{Btu/lb}) \quad \textbf{[A.11.5.2.b]}$$

In a partially confined space, the combustion energy will rapidly pressurize the space beyond what the silo walls or tops can withstand, causing destruction of the silo.

A.10.7 The objectives in fighting combustible metal fires are isolation and containment, rather than extinguishment. Water and other liquids have proved ineffective in extinguishing combustible metal fires. Streams of water intensify most combustible metal fires by feeding it oxygen. There is also the possibility of causing a steam or hydrogen explosion, particularly if large amounts of combustible metal are involved. The great affinity of high-temperature combustible metal for oxygen frees a considerable amount of hydrogen, which can reach explosive concentrations in confined spaces. Entrapment of water under any burning or hot combustible metal can result in a steam explosion.

Because of their unique nature, combustible metal fires demand a comprehensive fire protection plan wherever combustible metal is processed, handled, used, or stored. This plan should include specific actions in the event of a combustible metal fire and should be coordinated with the local facility management, responding firefighters, and medical personnel.

The plan should recognize the extreme hazards associated with combustible metal–water reactions that might occur with sprinkler water. Specific attention should be given to an evacuation plan for personnel in the event of any release of water.

Properly trained personnel who work with combustible metal know its hazards. Such personnel are best equipped to extinguish a combustible metal fire in its incipient stage. Training should include sufficient information to determine whether extinguishment can be accomplished safely and effectively.

A.10.7.3.1 One of the greatest dangers to firefighters is the splattering effect of burning alkali metals. Molten alkali metal is very fluid and easily spread; therefore, extreme care needs to be taken when applying firefighting agent. The force used to deliver agent from an extinguisher can cause the molten alkali to splash to adjacent areas. Therefore, the delivery technique is very important. If direct agent application becomes hazardous, indirect application techniques should be used. Deflecting agent off another object or directing the agent stream above the hazard and letting the agent fall by gravity can be effective.

A.10.7.3.2 Forming a crust over burning alkali metals reduces the available oxygen and eliminates exothermic reactions. Extinguishing agent should first be applied to the white-hot burning areas, then evenly applied to the mass, controlling the flow to form an oxygen-depleting crust. Since alkali metal tends to flow easily through any weak spots, agents should be applied evenly to construct a continuous crust. If the alkali metal surfaces, additional agent should be applied to strengthen the crust.

Important Notice: This document has been provided for NFPA technical committee member use only. This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2023 NFPA, and may not be used for any other purpose or distributed to any other persons or parties outside of the technical committee.

Actual crust formation is created by the ability of some powdered agents to absorb heat from the alkali metals. In the case of copper powder, an alkali metal–copper alloy is formed as heat is absorbed from an alkali metal. Once the crust is formed, the temperature of the alkali metal decreases and exothermic reactions are reduced. Extreme care should be taken to ensure that the crust is not disturbed or broken until the temperature of the alkali metal is decreased to the point where resolidification occurs (or in the case of NaK, until the mass is at or near room temperature).

A.10.7.4.6 It is recommended that a practice fire drill be conducted once each year to familiarize local fire department personnel with the proper methods of fighting Class D fires. Professional or volunteer firefighters from outside the plant cannot be expected to be trained for the specific fire and life hazards associated with metal powder and fires. In the interest of their own safety, they should be directed by the plant's safety officer or firefighting officer.

Public Input No. 105-NFPA 660-2025 [Chapter 11]

Chapter 11 ~~Reserved~~ ~~**Combustible Dust Fire and Explosion Investigations**~~

11.1 Responsibility

11.1.1* The owner/operator of a facility that has experienced any type or severity of combustible dust fire or explosion (hereinafter called an "incident") shall be responsible for retaining a qualified fire and explosion investigator to determine the most likely cause and origin of the incident, and to incorporate this information into the design of the new system to prevent or mitigate future occurrences of this type of incident in this system or equipment.

11.2 Qualifications

11.2.1* The investigation shall be performed or led by a qualified person. If a team is used for the investigation, each subordinate member of the team shall be a person who, by experience, education, or training can provide specialized knowledge that is deemed to be useful in the investigation by the lead investigator.

11.2.2 Qualified person

11.2.2.1* The lead investigator shall meet all the requirements for a fire investigator listed in Chapter 4 of NFPA 1033-2022 *Standard for Professional Qualifications for Fire Investigator.*

11.2.2.2 In addition, the lead investigator shall be a person who:

11.2.2.2.1 Is completely familiar with the procedures described in NFPA 921-2024 *Guide for Fire and Explosion Investigations* .

11.2.2.2.2* Is completely familiar with all the equipment, systems, processes, and materials involved in the incident.

11.2.2.2.3* Is completely familiar with the failure modes of the involved equipment and systems.

11.2.2.2.4* Is completely familiar with the specific hazards presented by each piece of equipment involved in the incident.

11.2.2.2.5* Is familiar with the specific hazards associated with the materials involved in the incident (i.e.: self-heating, reactivity, material handling issues, etc.), and who understands how tested combustibility parameters affect the susceptibility of the material to specific hazards.

11.2.2.2.6* Has documented experience with successfully completing investigations of combustible dust fires and explosions.

11.2.2.2.7* Is independent of the facility and/or corporate chain of command.

11.3 Investigation Procedures

11.3.1 Immediate aftermath of the incident

11.3.1.1* The scene shall be secured as soon as possible after any injured personnel have been removed from the area for treatment, the fires have been extinguished, and the area has been determined to be safe for personnel to enter.

11.3.1.1.1* Clean-up of the scene or removal of equipment or debris from the area shall be prohibited prior to the investigation.

11.3.1.1.2 Only authorized investigators and other personnel approved by the lead investigator shall be allowed to enter the secured area.

11.3.1.1.3 The scene shall remain secured until after the initial investigation is completed.

11.3.1.1.4 The scene shall be thoroughly documented by taking pictures and videos of the area.

11.3.2 Investigation

11.3.2.1 The investigation shall follow all applicable procedures recommended in NFPA 921-2024 *Guide for Fire and Explosion Investigations* .

11.3.2.2 The scientific method shall be used as the basis for the investigation.

11.4 Investigation Report

11.4.1 The investigation report shall detail the hypotheses that were developed, tested and either

accepted or rejected during the course of the investigation, and the methods used in making the determinations that are presented in the report.

11.4.2* The investigation report shall present determinations of (at a minimum) the cause of the incident, the origin point of the incident, the ignition source, and the sequence of events that led to the incident (Failure tree) to the highest degree of scientific/engineering certainty available based on the available evidence.11.4.2.1

11.4.3 The investigation report shall provide recommendations to prevent or mitigate the cause(s) and the failure tree to be used in the design of the new equipment or systems to prevent or mitigate future occurrences of this type of incident in this system or equipment.

Annex A Information

A.11.1.1 All combustible dust fire and/or explosions should be investigated. It does not matter whether it was a "small fire", a "small explosion", "not an OSHA recordable incident", or if it was just a smoldering fire. Even "small" incidents can be an indicator of a larger problem, and a "small" incident that was not investigated can become a larger incident later if the issues that led to the incident are not properly addressed and mitigated. This has been proven in multiple repeat incidents across industries for many years.

A.11.2.1 It does not matter whether the investigation is performed by a single investigator or a team of investigators and specialists, the lead (or individual) investigator must be fully qualified to perform the investigation to have any chance of successfully determining the cause of the incident.

A.11.2.2.1 One way of ensuring that the investigator meets the requirements in NFPA 1033 is to use a certified investigator. The oldest fire and explosion investigator certification is the National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator (CFEI). Another highly respected certification is the International Association of Arson Investigators Certified Fire Investigator (IAAI-CFI). While certification as a fire investigator is not the only qualification for investigating combustible dust fires and explosions, it does show that the certified investigator meets all the requirements of NFPA 1033, has been trained in the methods presented in NFPA 921, and has documented experience in (general) fire investigations.

A.11.2.2.2 These requirements are critical in properly determining the cause of the incident. There have been far too many combustible dust incidents in industry that were originally investigated by otherwise qualified investigators who were unfamiliar with dust collection equipment and the specific hazards this equipment presents, operation and limitations of combustible dust fire and explosion protection systems and the proper installation and maintenance of these systems, the materials involved in the fire and the specific hazards these materials present. The unfamiliarity with combustible dust equipment, systems, and materials caused these otherwise qualified investigators to come to incorrect conclusions and as a result, subsequent incidents occurred causing injuries to personnel and significant financial losses. In addition, investigators within the local facility or corporate chain of command can be overruled or unduly influenced by persons within the chain of command who can have different opinions or motivations than the investigator, whereas someone outside of the chain of command is free to follow the evidence wherever it leads.

A.11.3.1.1 The first thing to do at the scene of any incident is to ensure personnel safety and to get any injured personnel treatment. The second is to extinguish any fires, and the third is to make sure that the scene is as safe as possible for any subsequent investigators to enter. Once all of those things have been accomplished, it is critical to secure the scene to preserve evidence that is necessary in making accurate determinations of cause and origin of the incident and the failure tree that led to the incident. Accurate determinations are critical in preventing or mitigating future occurrences of the incident. Prohibit unauthorized personnel from entering the area by the use of barriers, signage, hazards tape, posted security personnel, or other methods deemed to be effective.

A.11.3.1.1.1 If any clean-up was performed or material was removed by anyone, including fire services personnel (fire marshals, fire fighters, or fire department investigators), get documentation of what was removed and contact information for anyone who removed material from the scene for the subsequent investigators. Any materials on or removed from the scene may be or contain evidence that is critical to properly determining the cause or origin of the event. Documenting any evidence that was taken from the scene and collecting the contact information of the persons who removed the evidence is necessary for any subsequent investigators. If the subsequent investigators do not know that evidence was removed, or do not know who previously investigated the incident or removed evidence, or how to get in touch with these people to interview them and review the reports that they generated, decreases the likelihood of the subsequent investigators making accurate determinations in their report.

A.11.4.2 Definitions of words used in describing the degree of certainty of a determination for use in these reports are as follows (From NFPA 921-2024):

Probable - This expression corresponds to being more likely true than not.

Possible - The hypothesis may be demonstrated to be feasible but cannot be either ruled out or declared probable. If two or more hypotheses are equally likely, then the expression must be “possible.”

Suspected - If the level of certainty of an opinion is merely “suspected,” the opinion does not qualify as an expert opinion. If the level of certainty is only “possible,” the opinion should be specifically expressed as “possible.” Only when the level of certainty is considered “probable” should an opinion be expressed with reasonable certainty.

Statement of Problem and Substantiation for Public Input

I have been on far too many incident sites with or after other investigators who, while qualified and experienced in general fire and explosion investigations, did not recognize or understand the equipment that was involved in the incident, the failure modes and specific hazards of the equipment, or how the equipment worked (one cause and origin specialist investigator with a master's degree in fire science thought the airlock under a dust collector was a fan - and after the investigation was completed, the airlock in question was determined to be the origin point of the fire that subsequently caused the explosion being investigated). I have seen many fires and explosions that were investigated either in-house or by certified investigators who were not familiar with combustible dust equipment, materials, and systems provide incorrect determinations of cause, origin and failure trees, that led to incorrect mitigation plans and subsequent larger and more costly (in terms of both financial cost and severe personnel injuries) fires or explosions. I have seen the results of in-house investigations where management had a pet theory about the cause and origin or had other motivations to put pressure on the in-house investigators to change their findings to conform with what management wanted to hear rather than following the evidence wherever it led. I have also seen the results of facilities not investigating "small fires or explosions" or smoldering events that led to larger fires and/or explosions that caused serious damage to the facility and equipment as well as injuries to personnel. This has to stop. By including the enclosed chapter and Annex A information into the fundamentals section of 660, we can prevent or at least deter events like the ones described in this statement from happening again. Further, the reason I believe this information needs to be included into the fundamentals section of 660 when other NFPA documents (1033 and 921) already exist is due to the general nature of the requirements in these documents, especially the information regarding the professional qualifications to be a fire investigator presented in NFPA 1033. The requirements presented in NFPA 1033 give several subjects for which a fire investigator shall maintain current knowledge, but nowhere in that standard are there any requirements for knowledge of and familiarity with any specialized equipment (beyond types of construction, fire protection systems, electricity and electrical systems, and fuel gas systems) or specific hazards associated with the equipment and materials that are necessary to properly investigate and correctly determine the cause and origin of highly specific fires and explosions like those that occur with combustible dust. The requirements in NPFA 1033 are the minimum knowledge required to be a general fire investigator. The information provided here goes beyond the general requirements and provides specific information pertaining to an investigator's qualifications to successfully perform a combustible dust fire or explosion investigation.

Submitter Information Verification

Submitter Full Name: Kevin Cardwell
Organization: Airdusco EDS, LLC
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 29 20:36:31 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-40-NFPA 660-2026

Statement: Most of the material from A.8.10 was relocated to other annex sections in this revision because it more appropriately aligned with other paragraphs.

New text has been added to A.8.10.1 to provide users with a list of the types of AHJs that are apt to be involved depending on the gravity of the event, and to emphasize that the incident investigation system should be sufficiently flexible to address a range of incident severities and

complexities.

Text was removed from A.8.10.2 that is now covered in A.8.10.4.

The language previously in 8.10.3 was split up into two related but distinct activities, and to provide additional guidance as annex content to each new section. The focus of 8.10.3 has been narrowed to securing the scene and collecting evidence, while 8.10.4 focuses on investigation team make-up and 8.10.5 on identification of causes.

A.8.10.3 emphasises the importance of taking steps to ensure that critical evidence is not removed or altered before the investigation can commence. It provides a recommendation that the structural stability of the scene be evaluated before personnel access is permitted, and provides additional guidance for control of the incident scene as part of the effort to protect evidence. It also identifies key activities that are commonly included in efforts to collect evidence to support the investigation.

New paragraph 8.10.4 focuses on the identification of the investigation team and clarifies the role of the person having responsibility for coordinating the investigation. This might or might not be the person leading the investigation team. Annex material in A.8.10.4 provides guidance on identification and qualifications of the investigation team lead and team members, emphasizes the importance of establishing the objectivity of the investigation leader and team so that the investigation produces unbiased conclusions, details the expertise and expertise that would typically be required for the investigation teams, and emphasizes that expertise needs can vary depending upon the complexity/severity of the event.

New paragraph 8.10.5 and annex material was added to address analysis of evidence, identification of causal factors, and proposal of recommendations.

New annex was added to 8.10.7 to provide additional guidance on resolving report recommendations and tracking them to their final implementation.

Note: The revision to paragraph A.8.10.8 regarding the time to retain an incident report is being balloted separately as First Revision 41.

Public Input No. 126-NFPA 660-2025 [Section No. A.3.3.21]

A.3.3.21 Conductive.

A typical threshold for solid materials would be a volume resistivity less than 10^5 ohm-m. (CMD-FUN)

The typical test procedures for Volume Resistivity include *ASTM D991, Standard Test Method for Rubber Property Volume - Resistivity of Electrically Conductive and Antistatic Products* , and *ASTM D257, Standard Test Methods for DC Resistance or Conductance of Insulating Materials* .

Statement of Problem and Substantiation for Public Input

The information on Volume Resistivity is from A3.3.36.2 in NFPA 77 (2019) and would provide additional guidance.

Submitter Information Verification

Submitter Full Name: Doug Thomas
Organization: North American Hoganas
Affiliation: MPPA
Street Address:
City:
State:
Zip:
Submittal Date: Tue Dec 30 13:00:51 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-32-NFPA 660-2026
Statement: The information on Volume Resistivity is from NFPA 77 and provides additional guidance.

Public Input No. 101-NFPA 660-2025 [Section No. A.3.3.84]

~~**A.3.3.84** – Noncombustible Material. –~~

~~When used in the context of materials of construction, materials that are reported as having passed ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C* , should be considered noncombustible materials. For the purposes of this standard, noncombustible construction and limited-combustible construction are both considered to be noncombustible. In this document, the term *noncombustible material* is also used to refer to process materials that do not present a fire, flash fire, or explosion hazard as per Chapter 5 . (CMD-FUN)~~

Statement of Problem and Substantiation for Public Input

PI 99 and PI 100 recommend revising the definition and annex note to be consistent with NFPA 5000 and other NFPA documents. The main concepts in this annex note are being retained and moved.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 99-NFPA 660-2025 [New Section after 4.2.7]	
Public Input No. 100-NFPA 660-2025 [Section No. 3.3.84]	
Public Input No. 99-NFPA 660-2025 [New Section after 4.2.7]	
Public Input No. 100-NFPA 660-2025 [Section No. 3.3.84]	

Submitter Information Verification

Submitter Full Name: Marcelo Hirschler
Organization: GBH International
Street Address:
City:
State:
Zip:
Submittal Date: Tue Dec 23 17:23:57 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: It would not be appropriate to make this change to the definition of "noncombustible material" within the context of NFPA 660 because this term is used to describe particulates as well as construction materials, and the proposed new text would not be accurate for particulates. Specifically, the text proposed for 4.3.1.3 references steel and aluminum as examples of noncombustible materials, which is definitely not the case in the particulate form. A Committee Input is being created to clarify the differentiation between combustible particulates (process materials) and combustible materials of construction. "Under the conditions anticipated" is an important part of the definition in order to include important criteria such as particle size, morphology, moisture content, and oxidizing environment.

Public Input No. 177-NFPA 660-2026 [Section No. A.5.3]

A.5.3

Some materials have multiple potential physical hazards such as combustibility, explosibility, reactivity, and propensity to self-heat. ~~Reactivity~~ Annex J of NFPA 400 contains a comparison of different definitions used by different standards, codes and regulations for Hazardsou Materials. Reactivity hazards can release energy and produce products that are more readily ignitible than the original material, thus creating or exacerbating a combustion hazard that would be within the scope of a DHA. Reactivity of combustible particulates by means other than self-heating could occur due to thermal instability or contact with an incompatible material. The ensuing chemical reaction could generate heat and gases, and the gases generated could be toxic, corrosive, or flammable.

Identification of potential incompatibility with water should be a high priority because humidity in the air might be sufficient to initiate reactions with materials that are incompatible with water. The need to know whether to avoid material contact with water is important, since water is often present at the site for process use, cleaning, utility use, or emergency response. Water is often the first choice as a fire extinguishing agent, so knowing whether to use or avoid water when extinguishing fires is critical.

Users should consult safety data sheets (SDS) for specific information and guidance on safe handling, personal protective equipment (PPE), and storage and transportation of chemicals.

Statement of Problem and Substantiation for Public Input

There are many different definitions used for hazardous materials and Annex J of NFPA 400 serves as a useful summary for users of NFPA 660.

Submitter Information Verification

Submitter Full Name: Timothy Myers
Organization: Exponent, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jan 07 14:27:46 EST 2026
Committee: CMD-FUN

Committee Statement

Resolution: FR-10-NFPA 660-2026

Statement: The title of this section is being revised to cover all of the hazards described within.

The section on "other hazards" is being moved after "Combustibility and Explosibility Tests" so to not split up the requirements that relate to combustibility and explosibility of combustible dusts. Sampling applies to all of the hazards described.

"Where required" has been added to the sections about testing, to clarify that testing may not be required based on the documented reviews in 5.4.1.2.1, 5.4.2.2.1, 5.4.3.2.1, and 5.4.4.2.1.

Text has been added to the annex to reference Annex J of NFPA 400, because there are many different definitions used for hazardous materials and Annex J of NFPA 400 serves as a useful summary for users of NFPA 660.

Public Input No. 102-NFPA 660-2025 [Section No. A.8.6.2.1]

A.8.6.2.1

A specific evaluation of the work environment to determine the requirement for the wearing of flame-resistant garments should be based on the potential hazards that workers are exposed to as part of their work duties.

Annex V. Guide for Computing Thermal Dose to Personnel for a Workplace Hazard Assessment provides an outline for the process for developing a personnel protection strategy and for quantifying the hazard to personnel for determining where Flame Resistant Garments (FRG) are needed and if FRG is sufficient to achieve the personnel protection objectives.

Statement of Problem and Substantiation for Public Input

Section 8.6.1 establishes a requirement but there is in information provided on how one determines if the requirement has been satisfied.Annex V has been written to provide extensive guidance for the user on how to quantitatively assess the hazard and means to manage it. The proposed text proved a necessary pointer to this resource.

Submitter Information Verification

Submitter Full Name: John Cholin
Organization: J. M. Cholin Consultants Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 29 12:42:49 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-34-NFPA 660-2026
Statement: Annex V has been written to provide extensive guidance for the user on how to quantitatively assess the hazard and means to manage it. This revision provides a reference to this resource.

Public Input No. 65-NFPA 660-2025 [Section No. A.9.4.17.1.8]

A.9.4.17.1.8

The operating control loop is intended for process temperature modulation. The excess temperature-limit safety interlock is a separate control method to shut down the heat source due to excessive temperature. Refer to NFPA 86 for additional information. It is good practice to have a temperature monitoring safety on the airstream at teh discharge of the drying chamber.

Statement of Problem and Substantiation for Public Input

the statement was moved from the main body to the annex as installing an outlet air temperature safety is a good practice, but not a fundamental requirement on all dryers.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 64-NFPA 660-2025 [Section No. 9.4.17.1.8]	

Submitter Information Verification

Submitter Full Name: Craig Froehling
Organization: Cargill, Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Fri Dec 19 12:40:56 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: CI-30-NFPA 660-2026
Statement: The committee agrees that revisions are needed based on Public Input 64 and 65, but additional time is needed to develop the text, specifically for non-heated air dryers. A task group has been formed.

Public Input No. 169-NFPA 660-2026 [Section No. A.9.6.6.1.4.4]

A.9.6.6.1.4.4

Propagating brush discharges, which are generally considered to be the most energetic type of electrostatic dischargein industrial applications, are widely accepted to be capable of producing ~~effective~~ energies on the order of 1000 mJ or higher . However, ~~high charging applications involving large surface areas are theoretically capable of creating propagating brush discharges with energies exceeding 1000 mJ. Subsection 9.6.6.1.4.4 establishes a limit of 2000 mJ to account for such instances and allow for commercially available testing to determine if a dust MIE is greater than 2000 mJ.~~ the maximum effective energy of propagating bursh discharges is probably about 1000 mJ.

The stored energy of a PBD can be much greater than 1000 mJ but only a small part of the stored energy is released in a small enough volume to contribute to dust evaporation/decomposition and ignition. Ian Pavey's paper "Propagating brush discharges in flexible hoses," Journal of Electrostatics May 2009, 251–255" reports measured stored energies between 12 mJ and 2000 mJ which is quite consistent with an effective energy of 1000 mJ given the large volume over which the propagating brush discharge dissipates its energy.

While this guidance is expected to be appropriate for most industrial applications, special care should always be taken to evaluate the process as part of the DHA to verify that insulative flexible connectors do not present an ignition hazard.

Statement of Problem and Substantiation for Public Input

The 2000 mJ criterion is tilted towards a single apparatus supplier while a different and acceptable criterion (closer to 1000 mJ) would be of general use and would be consistent with Larry Britton's book "Avoiding Static Ignition Hazards in Chemical Operations" (many instances) which states the maximum EFFECTIVE energy of PBDs is probably about 1000 mJ.

The stored energy of a propagating brush discharge can be much greater than 1000 mJ but only a small part of the stored energy is released in a small enough volume to contribute to dust evaporation/decomposition and ignition. Ian Pavey's paper "Propagating brush discharges in flexible hoses," Journal of Electrostatics May 2009, 251–255" reports measured stored energies between 12 mJ and 2000 mJ which is quite consistent with an effective energy of 1000 mJ given the large volume over which the propagating brush discharge dissipates its energy. Provided NFPA 660 does not specify a criterion above 1200-1400 mJ all other MIE apparatus described in ASTM E2019 should be able to make the measurement. Most were designed to measure MIEs somewhat above 1000 mJ, above which dusts are not regarded as significant static ignition risks.

NFPA 660's MIE criterion cannot be for a polydispersion (e.g., 5 – 500 microns) but should be measured for the finest "significant" size fraction present. Suggest the finest 20 wt% but some other number could be used. The dust fraction tested should be sub-200 mesh (or as specified in ASTM E2019).

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 168-NFPA 660-2026 [Section No. 9.6.6.1.4.4]	main requirement

Submitter Information Verification

Submitter Full Name: Eric Winter
Organization: Corteva Agriscience
Affiliation: NFPA 77 TG#8
Street Address:
City:
State:
Zip:

Submittal Date: Tue Jan 06 15:27:32 EST 2026

Committee: CMD-FUN

Committee Statement

Resolution: FR-38-NFPA 660-2026

Statement: Note: There is a separate revision (FR 39) that deletes 9.6.6.1.4.1 and A.9.6.6.1.4.1. This ballot item, FR 38, makes the other changes to 9.6.6.

Changes were made to section 9.6.6 and its annex to address the use of nonconductive equipment.

Section 9.6.6.1 was modified to specifically reference section 9.6.6.1.4 regarding flexible connectors where applicable, in response to PI 167. Note that the other changes proposed in PI 167 were not incorporated as the sections referenced did not refer to "equipment" in this context but rather personnel, containers, and industrial trucks.

Section 9.6.6.1.4.2 was modified to clarify the requirements for flexible connectors. A resistance to ground was specified instead of an end-to-end resistance value to better represent the critical variable in defining the potential for a propagating brush discharge. Additional subsections were added, along with annex text, to differentiate between flexible connectors having a grounded reinforcing wire and those without, as the resistance to ground may be determined differently for each case. The annex text for 9.6.6.1.4.2 was expanded to reference NFPA 77 for charge to mass ratios for process operations and ISO 8031 for testing of flexible conductors. Further explanation of the difference between connectors with and without grounded reinforcing wires was also provided.

Public Inputs 48, 49 and 98 proposed similar revisions for this section. PIs 48 and 49 proposed differentiating between conductive and antistatic flexible connectors, but the clarification of the resistance determination was deemed to be a better way to address the issue. Furthermore, PI 49 was overly prescriptive in the requirements for antistatic flexible connectors. PI 98 proposed adding a volume resistivity limit which would have created a second requirement within a single section, and this concern was addressed with the addition of 9.6.6.1.4.2(a).

A new section was added before 9.6.6.1.4.3 to explicitly allow for calculation of an alternative resistance to ground limit. This was done in recognition of the high material transfer rate that was assumed in defining the prescriptive resistance limit and to allow users to apply a different limit based on process-specific data. A table was provided to demonstrate the use of this alternative methodology.

The language in Section 9.6.6.1.4.3 (now 9.6.6.1.4.4) was modified to align with the changes made to 9.6.6.1.4.2 for consistency.

Section 9.6.6.1.4.4 (now 9.6.6.1.4.5) was revised to change the MIE threshold from 2000 mJ to 1000 mJ, as proposed in PI 168, with explanatory annex text. This is consistent with PI 168 and 169. This is consistent with Britton (1999) as a primary reference. The alternate reference provided in the substantiation for PI 168 and the proposed annex for PI 169 made reference to the incendivity of propagating brush discharges but did not demonstrate or quantify the issue beyond what was addressed in the Britton reference.

Public Input No. 103-NFPA 660-2025 [Section No. V.1]

V.1 Introduction.

~~NFPA 660 uses the determination of the existence of a *flash fire hazard* as the trigger for the requirement for the use of flame-resistant garments (FRG) to protect personnel from that hazard. Section 8.6.1.1 states: "Flame-resistant garments designed in accordance with NFPA 2112 shall be permitted to be used as part of the personnel protection strategy against localized flash fire exposures, only." This implies that there can be situations where the protective capabilities of FRG will not be capable of achieving the personnel protection objective. The methodology to evaluate this is critically needed.~~ insert attached MSWord file

Additional Proposed Changes

File Name	Description	Approved
Annex_V_28Dec2025_ACA.docx	This the working draft of the Annex V Task Group as of 28December 2025	

Statement of Problem and Substantiation for Public Input

Section 8.6.1 established a requirement in anticipation of an annex outlining the methodology for implementing the requirement. The task group work-product is attached

Submitter Information Verification

Submitter Full Name: John Cholin
Organization: J. M. Cholin Consultants Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Mon Dec 29 13:01:35 EST 2025
Committee: CMD-FUN

Committee Statement

Resolution: FR-35-NFPA 660-2026
Statement: This annex outlines a methodology for implementing the requirement in 8.6.1.

Annex V. Guide for Computing Thermal Dose to Personnel for a Workplace Hazard Assessment (CMD-FUN)

V.1 Introduction.

Relatively brief exposures to even small flash fire events can result in the ignition of ordinary clothing. Once an occupant's clothing ignites, serious and often fatal burn injuries are likely.[1] NFPA 660 uses the determination of the existence of a *flash fire hazard* from the DHA as the trigger for the requirement in Section 8.6.1 for protecting occupants from that hazard.

One option for protection of personnel is to require that those personnel, exposed to flash fire hazards from a deflagration, wear flame-resistant garments (FRG). NFPA 2112 provides requirements for the design of FRG and NFPA 2113 provides requirements for the selection and use of such personnel protective garments. NFPA 2113 requires that the facility operator perform a workplace hazard assessment to identify where within the facility the occupants should be equipped with FRG and provides general requirements for the workplace hazard assessment in Section 4.2.3. However, NFPA 2113 does not provide a detailed method for identifying where a flash fire hazard exists or explicit quantitative criteria for distinguishing hazardous areas from non-hazardous areas. This annex provides guidance on how to execute a quantitative hazard assessment for facilities covered under the scope of this standard.

Depending upon the fire scenario, the thermal flux (heat flow into the target) can be via radiation, convection or conduction, or a sum of more than one of the individual modes of heat transfer. Since this Annex addresses primarily when FRG should be used and when it should not be considered sufficient, it addresses only the first two heat transfer modes.

The user of this annex should remain mindful that FRG cannot provide adequate protection against all flash fire scenarios. The facility operator should ensure that FRG is not relied upon as a safeguard for scenarios where the intensity and/or duration of a flash fire can exceed the protective capabilities of the FRG.

V. 2 Workplace Hazard Assessment for Facilities within the Scope of NFPA 660

The Dust Hazards Analysis (DHA) should identify building compartments and areas where a flash-fire hazards exist. However, the DHA might apply the hazardous designation to an entire compartment or area when the hazard actually exists only in a fraction of a building compartment or expose only a fraction of the employees in the compartment. Consequently, the facility operator must have a means of establishing a dividing line between those areas where the hazard exceeds the facility fire safety objectives and where it does not. Furthermore, simply equipping all personnel with NFPA 2112/2113 FRG does NOT guarantee personnel safety. If the thermal output of a flash-fire at a given location exceeds the total thermal dose limiting capability of the garment, the injury to the personnel will exceed the tolerable limit.

The workplace hazard assessment process starts with the identification of the personnel safety objectives for the facility. Once the objectives are established, explicit performance criteria usually expressed as a radiant flux intensity (kW/m^2) or thermal dose (kJ/m^2) are derived from them. The performance criteria are used to determine where in the building compartment the potential thermal dose from a flash fire scenario is expected to result in personnel injury that exceeds the tolerable personnel injury for the facility. Once explicit personnel injury limits are established, each hazard area is evaluated to determine where in each area the thermal dose exceeds the personnel injury limits. Personnel occupying portions of the hazard area where the thermal dose exceeds the personnel injury limit must be protected or prevented from occupying that location. One means of protection for personnel under some, but not all, circumstances is equipping them with FRG.

However, the process does not stop with that determination. If FRG is to be relied upon the protective capabilities of the FRG must be sufficient to prevent injury. If the thermal performance of the FRG exceeds the thermal dose at a given occupant location, FRG can be used to achieve the safety objectives. If the thermal dose exceeds the protective capabilities of the FRG, that hazard area should not be occupied during time periods when the hazard exists.

This analytical process reflected in this Annex is summarized with Figure V1.

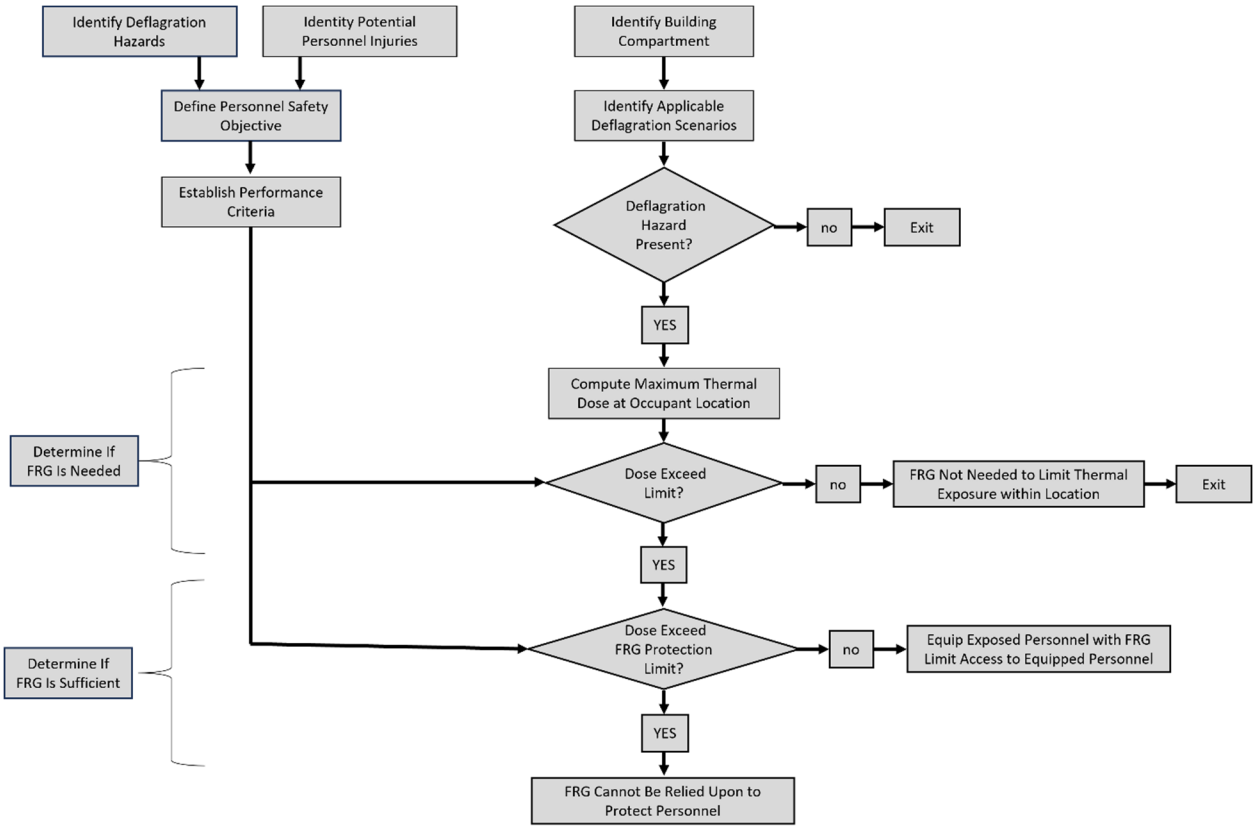


Figure V.1: The Analytical Process Reflected in Annex V

V.2.1. Hazard Management Strategy Development

The hazard management strategy development is started by establishing clear objectives for personnel safety. Once a personnel safety objective has been established, a qualitative or quantitative personnel protection criterion can be derived. This criterion will be used to determine if a protection strategy achieves the objective under a given fire or deflagration scenario. Fire and deflagration scenarios are then developed to determine if a strategy achieves the objectives. Deflagration scenarios are generally divided into "inherently limited deflagrations" in which the size of the deflagration flame is limited by the availability of fuel or some other limiting factor, and "building compartment deflagrations" (BCDs) in which the flame extension is limited only by the building compartment enclosure. BCDs usually are due to the effectively unlimited availability of fuel from accumulated fugitive dust. In each case, radiant intensities on or thermal doses for employee(s) under credible worst-case circumstances are computed. These radiant intensities and thermal doses are compared to the performance criteria associated with the personnel safety criteria to verify that the personnel protection objectives will be achieved.

V.2.2 Personnel Safety Objective

The first step in designing a personnel safety system is defining the maximum level of personnel injury that the facility is willing to tolerate. This establishes a personnel safety objective, usually in the form of a concrete objective statement like no personnel "shall sustain a permanent life-altering injury" or "suffer fatality".

It is not within the scope of NFPA 660 to establish injury prevention objectives for facilities covered by the scope of the standard. The facility owner/operator should do this. The owner/operator should understand that the design of personnel protection strategies begins with establishing injury prevention objectives. Once objectives are established concrete performance criteria can be developed that will serve as the basis for measuring whether a personnel protection strategy can or will achieve the objective.

V.2.3. Personnel Safety Performance Criteria

The personnel safety objective is used to establish performance criteria. These can be either qualitative or quantitative. A qualitative criterion might be the prevention of melting or ignition of occupant's clothing, which is likely to result in serious burn injuries or fatality. A quantitative criterion might be the thermal dose (kJ/m^2) necessary to produce the threshold injury to personnel established in the objective policy statement.

To evaluate the qualitative criterion of preventing ignition of clothing, the properties of the clothing are important. The ignition temperature for clothing varies considerably depending upon the type of fiber, weight of the finished cloth, age, etc. The ignition of ordinary clothing

made of cotton and polyester fabrics has been reported when it is exposed to relatively short-duration radiant flux on the order of 50 kW/m^2 in some references while other references report ignition at attained temperatures of 200 to 300°C.[2, 3] It is also conceivable that a facility operator would elect to have the melting and ignition characteristics of a specific type/brand of employee uniform tested to obtain data characterizing its performance criteria.

When the scenario involves an inherently limited deflagration and direct flame impingement or engulfment is not contemplated, thermal exposure to the occupant is strictly radiant and separation distance is one method that can be used to limit probability of injury. The radiant flux intensity and thermal dose criteria often used for personnel injury thresholds to bare skin are listed below, [4, 5]

Bright sunlight	1.37 kW/m^2
Pain threshold	41.9 kJ/m^2
Blister, severe 2nd-degree burn	83.8 kJ/m^2
Severe 3rd-degree burn	162.5 kJ/m^2

Note: Thermal dose (kJ/m^2) is radiant flux intensity (kW/m^2) multiplied by exposure time (seconds).

When the qualitative objective is similar to the "no permanent life-changing injury" objective, only the top two criteria are applicable. The severe 2nd degree burn criterion can be used. A thermal dose that leads to severe 3rd degree burn injury exceeds the level of injury implied by the objective and should be considered a "fatal injury" threshold.

In some cases, a facility operator might elect to use a more qualitative criterion. A qualitative criterion might be the prevention of ignition of occupant's clothing. Since ignition of clothing results in enormous and immediate thermal flux increase to the person, the objective of preventing serious permanently injurious burns ceases to be achievable and fatality becomes likely. The ignition temperature referenced above can be used.

In the case of burn injury hazard management, different personnel injury criteria will be applicable depending on the deflagration scenario. The chemical composition of the fuel and suspended particulate in the radiant flux transmission path, as well as the separation distance between the deflagration flame surface and the target occupant, all affect the radiant flux intensity impinging on the target occupant. These parameters should be stipulated in the deflagration scenario.

To evaluate the radiant and convective heat transfer potential, fire scenarios are developed that provide either the radiant flux or convective thermal flux that represents the design fire against which the fire protection strategy for the employees is evaluated.

V.2.4 Performance Criteria Selection

The facility operator should establish as a policy, the level of injury deemed tolerable versus intolerable in qualitative terms. That qualitative criterion can then be translated into a quantitative criterion suitable for engineering calculations.

For example, an operator could adopt a policy that no employee suffer pain lasting longer than 10 seconds as a consequence of a dust deflagration in the facility. Research has been reported that below a radiant flux of 1.7 kW/m^2 no subject reported pain regardless of exposure duration.[6, 7] Consequently, a radiant flux intensity of 1.7 kW/m^2 could be used as a quantitative criterion for this employee impact objective. It could be used to establish a lower bound, beneath which no exposure limitation is needed.

A relation has been developed to predict the occurrence of 2nd-degree burns (skin blister formation).[8] The data suggest that the difference in radiant flux leading to the on-set of blisters and severe blistering is small. Data for the onset of 3rd-degree burn injury was not available. Consequently, if the design objective is to prevent life-altering injury implied by the onset of 3rd degree burns, the relation below for 2nd degree burns can be used as a bounding-value estimate for the on-set of 3rd-degree burn injury criterion.

$$t_B = 200\ (\dot{q}'' / 1{,}000\ )^{-1.46} \qquad \text{eqn. V.1}$$

where: t_B = time to skin blister (sec)
$\dot{q}''$ = incident thermal radiant flux intensity (W/m^2)

This relation includes a 50% safety margin and its use with this safety margin is recommended to compute the time at which skin blistering has occurred when exposed to the radiant flux, $\dot{q}''$.[9]

Alternatively, an operator could adopt a policy that no employee suffers a permanent life-changing injury to more than 10% of her/his body as a consequence of a dust deflagration. This objective would tolerate burns to parts of the head, face or hands but would preclude the ignition of the occupant's clothing. In this case the radiant flux used to predict the ignition of clothing, usually on the order of 50 kW/m^2 or attained temperatures of 200 to 300°C, depending on the experimental conditions, could be used for the performance criterion.

For those locations where the deflagration flame volume is inherently limited by either the availability of fuel, the extent of the particulate suspension or the availability of oxidant (rarely the case in occupied building compartments) a minimum separation distance between the nearest occupant and the deflagration flame can be computed using the relations in Section V.3.2 to determine the separation distance needed to achieve the performance objective. However, if there is entrainable, accumulated fugitive dust in the building compartment, the deflagration flame volume ceases to be inherently limited and a building compartment deflagration (BCD) is

a likely result, see Section 3.1, below. In this case separation cannot be relied upon to manage the hazard to personnel.

For those cases where the flash-fire flame is expected to impinge on one or more occupants, a strategy for protecting those employees from the ignition of their clothing is critical. Usually, facility operators resort to equipping those employees in FRG. However, when this strategy is adopted, it is critical to verify that the FRG used will provide the level of protection needed. This also makes it necessary to quantify the circumstances where flame impingement is expected. Since the thermal protective capabilities of NFPA 2112/2113 FGR is finite, the use of NFPA 2112 FRG cannot guarantee that the wearer will not suffer bodily burn injury from a flame impingement or burns to the throat and lungs from flame engulfment from a dust deflagration.

V.3. Hazard Area Analysis

V.3.1 Fire and Deflagration Scenarios

The next step is to identify scenarios that would expose employees to a thermal hazard. Since the scope of NFPA 660 encompasses facilities handling combustible dusts, the scenarios would be derived from the DHA, focused on the thermal exposure of employees to flash-fires involving a deflagration of suspended dust or dust/solvent mixture.

The flash-fire exposure scenarios for facilities covered by NFPA 660 fall into two (2) categories. The first is a flash-fire resulting from the ignition of a dust suspension of inherently limited size. An example of this would be the ignition of a dust/air suspension or ignitable liquid vapor forced out of the ullage volume of a mixer during the addition of a combustible resin. This scenario is illustrated conceptually in Figure V.2.

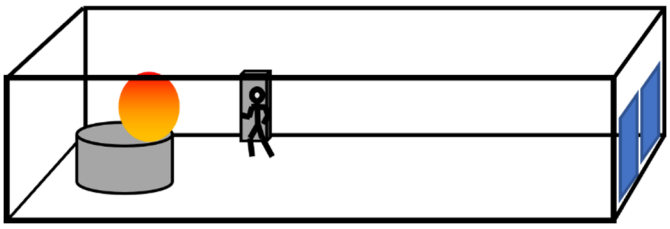


Figure V.2 The "Inherently Limited Deflagration" Scenario

As long as there is no accumulated fugitive dust in the building compartment that can be dislodged, suspended, entrained and ignited by the initial deflagration, the flash-fire is inherently limited by the quantity of fuel ejected from the mixer and the volume of the suspension or mixture. The distance between the source of radiant flux and the occupant is limited to the volumetric expansion of the deflagration flame. When considering this scenario, the analyst should consider the potential for the ejection of additional fuel (dust) out of the process vessel by

the force of the deflagration that can expand the deflagration flame volume as the ejected dust mixes with fresh air and burns..

The second scenario is where an initial deflagration occurs in a building compartment where there exists a combustible dust suspension or where fugitive combustible dust has accumulated on interior building compartment surfaces. In this scenario the accumulated dust load is often dislodged and dispersed by the pressure pulse from the initial event. The flame of the initial deflagration ignites the suspended dust, resulting in a deflagration flame front propagating across the interior volume of the building compartment. This scenario, a building compartment deflagration (BCD), is illustrated conceptually below.

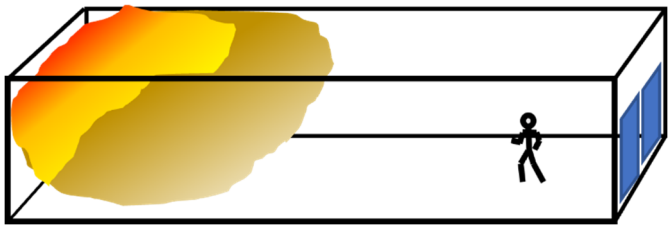


Figure V.3 The "Building Compartment Deflagration" Scenario

As the deflagration flame-front propagates through the dust suspension within the building compartment interior, the expanding combustion product gases behind it force both the flame and the suspended, unburned dust cloud across the interior volume of the building compartment. In this case the source of radiant flux is moving towards the occupant, rapidly increasing the radiant flux intensity impinging on the occupant. Furthermore, since the flame-front has a supply of fuel, the requisite conditions to continue the combustion spreads across the compartment interior. The burning cloud should be expected to impinge on any occupants in the building compartment.

V.3.2 Estimating Radiant Flux Hazard

There are a number of computational methods for estimating the radiant flux impinging on a target as a function of a given fire geometry.[10] The suitability of a computational method for a given fire/deflagration scenario depends on the fire/deflagration scenario and the performance objectives for the facility design.

Since the radiant flux from a deflagration is determined by the size of the dust suspension, the fuel and the dust concentration, any deflagration scenario begins with the stipulation of these quantities as a "source definition". For the inherently limited deflagration scenario this usually entails the assumption that the entire interior of an enclosure is occupied by a dust cloud at the worst-case concentration, c_w. For the BCD scenario, while the deflagration might begin with a localized deflagration flame, the existence of a dust cloud in the building compartment provides the fuel needed to extend the deflagration flame across the compartment interior. This allows the radiating area of the flame to expand to the full cross-sectional area of the building compartment

as well as travel towards the target occupant. Both of these result in a significant increase in the predicted impact on personnel.

In this annex, the calculations yield a computed radiant flux intensity measured in kW/m^2. Injury is the consequence of a thermal dose measured in kJ/m^2. Since the reaction of personnel to a deflagration incident is rarely predictable exposure time is impossible to accurately quantify. Consequently, the radiant intensities calculated are compared to performance criterion radiant intensities rather than doses associated with personnel safety objectives.

V.3.2.1 Inherently Limited Deflagration of Particulates (Dusts)

There are two mathematical relations in common use for estimating the radiant emissions from a fire. The first is based upon the heat release rate of a point-source. The second is based upon the flame temperature of point-source. The user of this Annex should select the relation used to estimate the radiant flux of the deflagration based upon on the available data regarding the fuel involved. Each relation is subject to its own uncertainties, limitations and underlying assumptions.

The relation based upon the heat release rate of the "point-source" radiator has been validated for hydrocarbon liquid fires. The flames are "diffusion" rather than "pre-mixed" flames. The relation can be applied to non-metallic dusts based upon the presumption that ordinary (non-metallic) fuels pyrolyze upon heating, yielding pyrolyzate vapors that burn like hydrocarbon liquids. It assumes that the customarily used "radiative fraction" for such fires is appropriate. Additionally, the error from approximating a definite area as a point becomes large as the separation distance becomes smaller compared to the area. This relation is not applicable to metallic dusts.

The relation based upon flame temperature of a point source is based on the presumption that dust deflagration flames emit radiation that can be quantified using Planck's Law and a Steffan-Boltzmann correction for "gray body" emissivity. But flames, especially those of burning vapors and gases, are not solid masses but, instead, mixture of gaseous oxidized fuel molecules that should not be modelled as a "black-body" or "gray-body" radiator. Only the oxides resulting from the combustion of metallic particulates are solid metal oxide particles and a gray-body radiator approximation can be applicable to these fuels. But the user should keep in mind that flame temperature measurements are dependent on the combustion conditions and measuring method. If the temperature is inferred from pressure data for a stoichiometric concentration it might not accurately predict the flame temperatures of an accidental uncontrolled deflagration.

Consequently, both relations presented in this annex are inherently imprecise due to uncertainties in input parameters. The user is urged to perform a sensitivity analysis on all calculations.

V.3.2.1.1 Heat Release Rate of a Discrete "Point-Source" Relation

To estimate the radiant emission from an inherently limited deflagration (flash-fire) of a non-metallic particulate, a "point-source" approximation for a discrete "fireball" can be used. This approximation is developed from an estimate of the heat release from the deflagration and a calculated radiant flux intensity impinging upon the contemplated target individual. For combustible dust processing facilities, the heat release estimate is usually derived from the maximum anticipated dust suspension cloud volume at the worst-case concentration, c_w, the concentration at which P_{max} was attained during testing. Clearly, the dust suspension cloud volume estimate is dependent on the facility and its particular process equipment. It is critical to limit the use of this calculation to only those facilities where there are no suspendable or entrainable dust accumulations adjacent to the dust suspension cloud that could extend the combustion zone beyond the volume considered in the scenario.

One computational model that is applicable to the inherently-limited deflagration is the point-source/inverse-square law model. This computational model is widely used. It is used for the design of fire detection systems using radiant energy-sensing fire detectors in NFPA 72, The National Fire Alarm and Signaling Systems Code.[11] Even though an actual fire has height and width, the energy release from the fire is treated by NFPA 72 as a quantum radiator emitting radiant energy from a point on the center of the front (nearest) surface of the optically dense flame. The radiant flux intensity (radiant power per unit area) at the detector (the target) is computed based upon the sensitivity of the detector that is derived from the product Listing investigation, the radiant flux intensity of the source and the Inverse-Square Law.

Drysdale models the radiant power from an ignitable liquid pool fire as a Planckian radiator emitting with a radiative fraction, X.[12]

The application of this relation to predicting radiant flux from a deflagration (flash fire) is addressed by Beyler in the SFPE Handbook, Chapter 66. For a hypothetical point-source radiator the incident radiant flux, q, impinging on a target a specified distance from the deflagration center can be predicted using the relation:[13]

$$q = \tau X_r (Q/4\pi L^2) \cos\Theta \qquad \text{eqn. V.2}$$

where q = Received radiant flux (kW/m^2)
τ = Atmospheric transmittance (unitless)
X_r = Radiative Fraction of the heat release. (fractional value)
Q = Heat release rate (kW)
L = Distance from center of fire ball to target, (m)
Θ = Angle of hypothetical target plane to flame exposure path

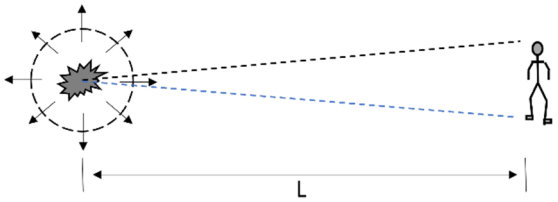


Figure V.4 The Point-Source Model for Radiant Emission from a Deflagration to a Target Occupant

Since the "target" in this annex is a human that has roughly the same exposed surface regardless of what direction the person was facing, the angle between the target plane and the radiant flux vector is always 90°. This makes cos $\Theta = 1$. Secondly, we assume a worst-case circumstance with no atmospheric absorbance in the transmission path, meaning transmittance is 100%, making $\tau = 1$. Correlations have been developed for radiative fraction based upon vapor pressure for gaseous releases but none exist for clouds of combustible dusts. [14]

To use this relation, one must have a value for the heat release rate of the deflagration. This can be computed from the total heat release divided by the deflagration flame duration. For deflagration flames that run their course in 1 second, a bounding value estimate for the radiant flux intensity from a dust deflagration can be obtained by computing the mass of dust suspended in the dust suspension cloud, assuming worst-case concentration, c_w, the net heat of combustion of the fuel, ΔH_c, and a numerical value for radiative fraction, X_r.

The radiative fraction, X_r, is reported to have values from 0.1 to 0.4.[15] Customarily, fire protection engineers use a radiative fraction, X_r, of 0.3 to 0.35 for diffusion flames. This value for X_r has been derived from research primarily focused on hydrocarbon pool fires, and for flammable gas and vapor cloud fires. There is very limited research investigating a radiative fraction for deflagration flames involving combustible dusts. Where commonly encountered particulates like agricultural, forest, animal-derived and plastic products are concerned, the fuel particulate must first pyrolyze into ignitable vapors, chemically similar to ignitable liquid fuels, before burning. Consequently, it is unlikely that the use of this value for X_r for those dusts introduces an unacceptable error. However, this has not been explicitly validated yet. The value for Q is a function of the total heat released in the fireball and the duration of the fireball. See section 3.2.1.4 for calculation details.

The point-source/inverse-square law model becomes increasingly less reliable as the distance between the deflagration flame and the occupant decreases. The point-source approximation is applicable only in scenarios where the separation distance (L) is much greater than the diameter (D) of the fireball. At closer distances, the point-source method has been shown to under-predict heat fluxes to a target. As a general guideline, the point source model should not be applied where the estimated heat fluxes at the target are below 5 kW/m^2.[16]

V.3.2.1.2 The Spherical Fireball Model

An alternative method to obtain a radiant flux estimate is to compute the circular radiating area of the optically dense spherical suspension and apply an average surface emissivity and geometrical configuration factor between the fireball and target.

Flames are optically dense (also called "optically thick") radiators. This allows one to base the calculations on the radiating area of the flame and an average emissive power per unit of area rather than on the actual flame volume. Furthermore, the radiating area consists only of that portion of the surface of the flame that has a direct transmission path to the target. This allows us to model a spherical deflagration as a circular radiating area of the same diameter as the spherical flame with an average emissive power per unit area.

An average emissive power per unit area of 350 kW/m^2 is widely used for ignitable liquid and flammable gas deflagrations.[17] The value of 200 to 350 kW/m^2 has been suggested for the average emissive power for BLEVE deflagrations.[18] It is important to keep in mind that when an average emissive power per unit of deflagration flame area is used, one should not apply the radiant fraction, X_r, correction because the numerical value for the average emissive power is the measured radiant power from a fire of known total heat release rate. With the above in mind, equation V.3 can be used to compute an estimate of the radiant flux intensity impinging upon a target (occupant) at known separation distance from a deflagration of known HRR.

When using an average emissive power, E, (kW/m^2) to model the deflagration, it is generally expressed as:[19]

$$q = \tau E F \qquad \text{eqn. V.3}$$

where q = incident radiant power intensity (kW/m^2)
τ = transmissivity of medium, air (%)
E = average surface emissive power intensity (kW/m^2)
F = geometric configuration factor

Assigning the value of 1 to τ for clear air and surface emissive power intensity of 350 kW/m^2 for hydrocarbon fuels, equation V.3 becomes:

$$q = 350F \qquad \text{eqn. V.4}$$

Since the parameter E has units of kW/m^2 it is an "intensity", the total emissive power (kW) is found by multiplying the surface emissive power intensity by the radiating area of the deflagration flame.

The configuration factor is calculated as a function of the expected fireball dimensions and separation distance to a target using the method presented by Beyler. [20]

$$F = (r^2/L^2)\cos\Theta \qquad \text{eqn. V.5}$$

where r = radiator radius, ½ radiator diameter
L = separation distance from center of flame to target
Θ = angle of incidence to front surface of target

This method presumes that the radiant flux from a spherical deflagration flame is impinging on a flat absorptive surface that is not necessarily at right-angles to the line from the center of the radiator to the center of the target. This is NOT the case when considering the potential for personnel injury. It does not matter what side of a person's body is burned or which side of her/his clothing ignites. In the case of personnel radiant impingement, the angle of incidence, Θ, is always 90° and the cos Θ is 1. For this case, Equation V.5 reduces to: [21]

$$F = r^2/L^2 \qquad \text{eqn. V.6.}$$

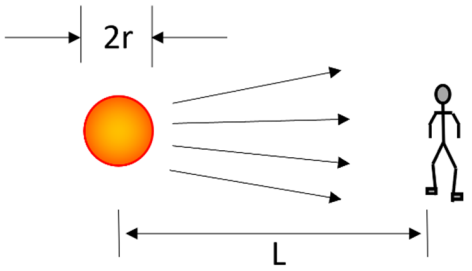


Figure V.5: The Parameters in the Configuration Factor for Heat Release Rate of the Spherical Fireball Model Relation

V.3.2.1.2 Flame Temperature of a Spherical Fireball Relation

As an alternative to the assumed average surface emissive power value of 350 kW/m^2, the radiant thermal flux from a flame can also be calculated from the flame temperature and the radiating area as a Planck's Law radiator. This relation does not rely on the use of experimental radiant flux data obtained from ignitable hydrocarbon gases and liquids, making it useable for both the "ordinary" combustible particulates as well as the combustible metals. Metallic

particulates burn with sufficiently different chemistries yielding very different combustion products and often with far greater heat release per unit of fuel mass.

When metallic or other particulates that cannot be approximated with hydrocarbon liquid equivalence are involved, the following relation should be used as the computational model. Rather than starting with a value for heat release rate, equation, V.2 is rewritten based upon the flame temperature, the Steffan-Boltzmann relation for "gray-body" radiators and combined with the Inverse-Square Law portion of the point-source relation of eqn. V.2. The combined relation is:

$$q = \tau\varepsilon\sigma (T_f^4 - T_a^4) r^2 / L^2 \qquad \text{eqn. V.7.}$$

where q = Received radiant flux (kW/m^2)
τ = Atmospheric transmittance (unitless)
ε = Steffan-Boltzmann emissivity of radiator (fractional value)
σ = Steffan-Boltzmann constant, 5.67E-11 $kW/m^2°K^4$
T_f = Flame temperature, °K
T_a = Ambient temperature, °K
r = Radius of deflagration flame
L = Distance from center of fire ball to target, (m)

This relation requires a numerical value for the Steffan-Boltzmann emissivity, ε, of the deflagration flame. This factor serves a similar purpose as the radiative fraction, X_r, in equation V.2. It should be experimentally obtained but is often assigned a value of 0.8. A bounding value of 1.0 can be used to obtain a conservative result.[22] The actual emissivity of a deflagration flame is the sum of the quantum emissions resulting from the chemical reactions in the flame and the gray-body emissions from the heat content of the combustion products. The gray-body fraction can be derived from the sum of emissivity of the each of the combustion products multiplied by their fraction of the total combustion product mass. Keep in mind that the combustion products of a metal dust deflagration are the metal oxides resulting from the combustion reactions that are usually solid particulates.

Flame temperature must be obtained from relevant research. The flame temperatures for diffusion flames involving hydrocarbon fuels are generally on the order of 1,400 to 1,600 °K (1,100 to 1,900 °C). [23] Combustible metal particulates burn at much higher temperatures. The flame temperatures for combustible metal particulates in air suspension are shown in Table V.3.2.1, below.

Element	Flame Temperature, °K [24]	Heat of Combustion MJ/kg [25]
Aluminum	2800-4000	31.06
Boron	1700	58.83
Carbon	1700-2600	
Chromium	1850-3170	10.78
Hafnium	2400-4850	
Magnesium	2850-3600	24.73
Molybdenum	2600	
Nickel	2400	
Niobium	2100-3540	
Tantalum	2350-3750	
Tin	1550-2250	
Titanium	2850-3990	19.6
Tungsten	1550-3100	4.59
Zinc	1750-2070	5.37

Table V.3.2.1 Flame Temperatures and Net Heat of Combustion for Combustible Metal Particulates.

The data for metal dust deflagration flame temperature were not directly measured but rather were computed from pressure data obtained using the U.S.B.O.M 20-liter hemispherical test apparatus. The data for heat of combustion were derived from oxygen consumption cone calorimetry. Published data for other metallic particulate deflagrations has not been found.

Zalosh provides relations for flame radiation based on flame temperature that are similar to the above relations.[26]

3.2.1.4 Using the Relations for an Inherently Limited Deflagration

These relations are suitable for a scenario similar to that in Figure V.2 where the deflagration is inherently limited and is not constrained by building compartment floor, ceiling or walls.

Since the scenario presumes an inherent limitation in the diameter or volume of the deflagration the first step is to establish the maximum, credible worst-case size of the deflagration. This provides the starting point for the calculations that can be used to determine if separation distance can be used as a hazard management method. The scenario is determined by the process environment and the particulate involved. Usually, the scenario is the ignition of the dust/air mixture in the ullage volume of process vessel or the release of a mass of dust into the interior of a building compartment.

Generally, the maximum dust suspension volume at the worst-case concentration, c_w, is assumed to be present and ignited. But this is NOT a bounding-value assumption. Dust concentrations above c_W will still support a deflagration flame-front and eject incompletely burned fuel ahead of the flame. As the unburned and partially burned fuel mixes with fresh air it extends the flame-

front. The deflagration size criterion used for the calculations should address this potential. This is usually done by increasing the volume of the fuel cloud before ignition to evaluate the impact of fuel concentrations above c_W.

Also, it is critical to ascertain that the dust release is truly limited. The potential for the involvement of additional dust should be considered and added to the computed dust cloud fuel load if there is a reasonable likelihood of additional fuel entering into the deflagration scenario such as the ejection of settled dust out from a vessel. If there is the potential for entrainment of previously settled dust on upward-facing accumulation surfaces exterior to the process vessel under consideration, the scenario should be treated as a building compartment deflagration scenario as in Section V.3.2.2, below

Once the design scenario dust suspension has been determined the radiant power from the deflagration is determined. Radiant power is computed from the total heat of combustion and the flame duration. The duration of the flame is derived from the flame speed and the diameter of the dust suspension. The speed of the flame-front through the dust suspension is the fundamental burning velocity, S_u. A relation has been cited that can be used to derive an estimate of the fundamental burning velocity, S_u. [27]

$$S_u = K_{St} / 4.84[(P_{max}/P_0)-1]P_{max} \qquad \text{eqn. V.8}$$

Where S_u = Fundamental burning velocity, m/sec
K_{St} = Measured Deflagration Index obtained per ASTM E 1226, bar-m/sec
P_{max} = Maximum deflagration pressure, bar
P_0 = initial pressure, bar

This relation can be used to estimate the burning velocity, S_u. The deflagration flame duration can then be estimated with:

$$t_f = D/S_u \qquad \text{eqn. V.9}$$

where t_f = flame duration time, sec
S_u = Fundamental burning velocity, m/sec
D = Dust suspension cloud diameter, m

Once the deflagration flame duration, t_f, is known the radiant power of the deflagration flame can be computed.

$$Q = \rho V(\Delta H_c) / t_f \qquad \text{eqn. V.10}$$

where Q = Radiant power, kW
ρ = Dust concentration in cloud, kg/m^3
V = Dust cloud volume, m^3

t_f = flame duration time, sec
ΔH_c = Net heat of combustion of fuel, kJ/kg

For example, a process is handling a wood particulate with K_{St} = 100 bar-m/sec, P_{max} = 8.0 bar-abs. The ΔH_c = 20 MJ/kg. The worst-case concentration, c_W = 400 g/m^3. The deflagration scenario is a 2.0 meter diameter spherical dust cloud.

From equation V.8 S_u = 0.55 m/sec. From equation V.9, the 2.0 meter diameter dust suspension will yield a flame time, t_f = 1.1 sec. The 2.0 m diameter dust suspension has a volume of 4.18 m^3. Using equation V.10. we estimate the total radiant power of 30,400 kW. The radiating area of the deflagration is 3.14 m^2 and 1/6 of the radiant flux is radiated toward the target. This yields a radiant flux intensity of approximately 1613 kWm^2. This value is larger than the 350kW/m^2 used in equation V.4, above. Remember that the 350 kW/m^2 value is experimentally obtained from a diffusion flame while the calculated value here is from a hypothetical premixed flame at worst-case concentration.

Equation V.2 can be used to calculate the received radiant flux intensity, q, in kW/m^2 as a function of separation distance, L, in m for a deflagration flame of given volume. Since both the cos Θ and τ terms are equal to 1, equation V.2 can be reorganized to be explicit in L to obtain the distance at which the received radiant flux intensity is equal to a specified value under a scenario of a given deflagration radiating area and heat release rate of Q, as shown.

$$L = (X_r Q/4\pi q)^{1/2} \qquad \text{Eqn. V.11.}$$

When using equations V.4 and V.5, reorganizing for a form explicit in L yields:

$$L = (350 r^2/q)^{1/2} \qquad \text{Eqn. V.12.}$$

These relations can be used to compute the minimum separation distance between the deflagration and the occupant needed to limit the radiant flux intensity to a given level based upon the size and heat release rate of the deflagration.

Similarly, when using the point-source flame temperature calculation and setting τ = 1, equation V.7. can be reorganized to be explicit in L, the separation distance at which the received radiant flux intensity is equal to a specified value under a scenario of a given deflagration flame temperature, T_f, as shown.

$$L = [r^2 \varepsilon \sigma (T_f^4 - T_a^4) / q]^{1/2} \qquad \text{Eqn. V.13.}$$

This relation can be used to compute the minimum separation distance between the deflagration and the occupant needed to limit the radiant flux intensity to a given level based upon the size and flame temperature of the deflagration.

V.3.2.2 Building Compartment Deflagration of Particulates (Dusts)

When the radiator is a building compartment deflagration (BCD) flame-front, the radiant flux intensity at a target occupant cannot be estimated from a simple point-source inverse-square relation. In the BCD scenario we presume that the deflagration begins either in a pre-existing dust cloud with a concentration sufficient to propagate the deflagration flame front occupying a large fraction of the compartment interior volume, or in a compartment with pre-existing dust accumulations that can become dispersed into the interior volume as a result of the initiating event.

Once ignition occurs, the deflagration propagates radially as a spherical flame-front. The radiant source both expands in area and advances across the compartment interior, presumably towards the target. Consequently, the method of calculating the radiant exposure at the target occupant should address the dynamic behavior of the propagating BCD. This is customarily done with a series of successive calculations iterated for short intervals of time as the flame-front propagates towards the target occupant. For a deflagration ignited at the edge of a dust suspension at the end of a building compartment one can envision the initial phase of the event as in Figure V.7.

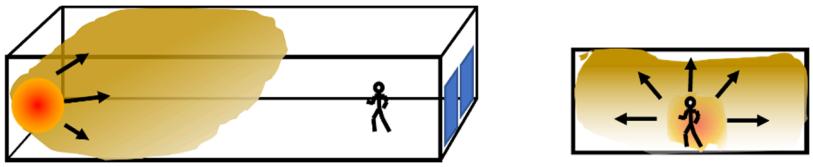


Figure V.7. Initial Phase of a BCD, Side View and End View

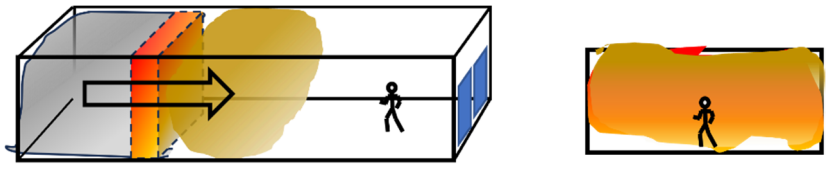


Figure V.8. The Modeled BCD Radiator Once Wall Constraint Occurs

When considering the BCD scenarios there are three factors that must be added to the calculations. The first is that the interior building volume between the deflagration flame and the target occupant is NOT totally transmittent, as was assumed in the case of the Inherently Limited Deflagration, above. Second, the radiating area of the deflagration is NOT a defined size, it is increasing in area until constrained by the building structure. Third, the deflagration flame front is advancing across the compartment interior. The latter two factors are both functions of time. These factors are considered below in that order.

When there is a dust suspension in the compartment interior equations V.2, V.7, V.8., V.9., and V.10. must be modified by adding a Beer-Lambert Law absorbance term to address the absorbance of radiant energy due to the pre-existing dust suspension.

Beer-Lambert Law optical absorbance is usually computed with:[28, 29]

$$I = I_0 e^{-\mu L} \qquad \text{eqn. V.14.}$$

where I = received radiant flux intensity, kW/m^2
I_0 = initial radiant flux intensity, kW/m^2
e = Naperian logarithm base
μ = atmospheric absorbance coefficient, m^{-1}
L = distance, m

Using the variable q" to designate the reduced radiant flux intensity at the target surface as a result of the absorbance, Equation V.2 is modified with the addition of the Beer-Lambert Law absorbance by the transmission medium to obtain equation V.13.

$$q'' = e^{-\mu L} X_r Q / 4\pi L^2 \cos\Theta \qquad \text{eqn. V.15.}$$

where the parameters are defined as above. Similarly, equation V.7. becomes:

$$q'' = e^{-\mu L} \varepsilon\sigma (T_f^4 - T_a^4) r^2 / L^2 \qquad \text{eqn. V.16.}$$

To use these relations, the absorbance coefficient, μ, of the dust suspension must be quantified. Unfortunately, no research has been found providing numerical values for μ for combustible dusts as a function of concentration. The atmospheric absorbance of a concentration of coal dust at the minimum explosible concentration (MEC) is often cited as being "totally obscuring" over a distance of 3 m.[30] The phrase "totally light obscuring" is not sufficiently precise for engineering. 90% obscuration (10% transmittance) leads to an absorbance coefficient, μ, of 0.77.

However, optical obscuration is the result of both the absorbance as well as the reflection of radiant energy. Consequently, white or light-colored particulates also produce obscuration.

For most commonly encountered combustible dust powders one would expect a smaller absorbance coefficient than that computed for coal dust. Using a coefficient of 0 means there is no light obscuration, either by absorption or reflection by the particulate, and resulting in no attenuation of the radiant flux intensity by the atmosphere between the deflagration and the occupant in the calculation. This maximizes the computed received radiant flux intensity at the occupant and is a "bounding value". Once the particulate is known a numerical value for μ should be determined by testing.

Equations V.12 and V.13 allow the computation of the radiant flux intensity impinging on a target occupant at a given distance from the flame surface during the initial phase of the BCD development, before wall, ceiling or floor constraint.

Once constraint begins, the user should model the deflagration flame as a flattened surface advancing towards the occupant. Since the BCD flame has an extended fuel supply ahead of it, that allows the flame-front to expand, the process of estimating the radiant flux on a target occupant requires computing the radiating area of the flame as a function of time.

The rate of flame area increase is proportional the square of the flame speed through the dust cloud, the flame-front velocity. The flame-front velocity is also used to determine when the deflagration flame constraint by the building occurs.

The flame speed through the dust suspension, S_u, can be computed from test data for K_{St}. [31]

$$S_u = K_{St} / 4.84[(P_{max}/P_0)-1]P_{max} \qquad \text{eqn. V.17.}$$

Where K_{St} = Measured Deflagration Index obtained per ASTM E 1226
P_{max} = Maximum deflagration pressure, bar
P_0 = initial pressure, bar

This relation provides the rate at which the radius of a spherical deflagration flame and hence the circular radiant emitter is increasing until wall constraint occurs. This provides the rate of radiating area increase.

Once wall constraint occurs the radiating area of the deflagration is limited to the compartment cross-section but the flame-front accelerates towards the target occupant. Eckhoff offers a relation for the speed of the flame front:[32]

$$S_f = S_u + S_g \qquad \text{eqn. V. 18.}$$

where S_f = speed of the flame layer relative to a stationary point, the occupant
S_u = flame speed through the dust cloud, the fundamental burning velocity
S_g = speed of the surface of the combustion product gas volume

Eckhoff also states that under ideal, adiabatic conditions the ratio S_f/S_u is approximately 7.5 for most organic compound fuels.[33] Eckhoff notes that this is also the combustion product expansion ratio, the final deflagration product volume to initial fuel suspension volume, for this category of fuels.[34] (Eckhoff uses the E for this parameter, we use Z to avoid confusion with the parameter E used above in equation V.3.)

$$S_f = S_u Z \qquad \text{eqn. V.19.}$$

This relation provides an estimate of the flame-front velocity through the dust cloud. For metallic particulates an expansion ratio of 10:1 is commonly used since the expansion ratio is generally proportional to the measured P_{max} to ambient ratio.

Once an estimate for the flame speed has been developed, one can estimate the radiant flux from the expanding deflagration using the area of an optically dense circular radiator to model the deflagration flame for the time period before wall constraint. Since the BCD scenario contemplates a pre-existing dust cloud, the atmospheric extinction should be included in the calculation. Either equation V.13 or V.14. can be used to compute the radiant flux intensity at a target occupant located a given distance from the deflagration. If an average emissive power is used for the deflagration as in equation V.4. and V.5., and $\Theta = 90°$, $\cos \Theta = 1$. Equation V.13 can then be rewritten as:

$$q'' = e^{-\mu L}(350\ \text{kW/m}^2)(r^2/L^2) \qquad \text{eqn. V.20.}$$

This relation allows one to compute the radiant flux intensity on the occupant as the deflagration flame-front advances towards that occupant in a succession of short time intervals. This allows one to estimate how long after ignition the conditions at the target exceed the criteria for the personal injury prevention objective for the facility.

3.2.2.3 Using the Relations for a BCD

In the BCD scenario there is either a pre-existing dust suspension in the building compartment atmosphere or the mechanical impulse from the initial flame front expansion, (pressure, shear force, vibration) suspends dust that has accumulated to hazardous levels within the building compartment. Since the deflagration flame volume is increasing in time a simple explicit relation does not suffice to identify the point when the conditions exceed the personnel protection criterion.

In the initial phase of the deflagration, before constraint by the building compartment enclosure, equation V.2, V.3. or V.7, above, can be used to compute the radiant flux intensity on the occupant as a function of time. This can be done by step-wise, successive calculation using a spreadsheet such as Excell or equivalent.

Using a flame speed, S_u, of 0.62 m/s (a value from research Eckhoff cites for corn starch)[35] the expected flame front velocity, S_f, would be 4.65 m/s. This is the rate the radius of a circular radiating area of the unconstrained deflagration flame is increasing. (Keep in mind this numerical value is only appropriate for corn starch.) Since the flame front is an optically dense radiator, the radiating surface facing a target occupant is circular. This leads to an estimate for the radiating surface area 1.0 second after ignition of 67.9 m^2. Another second later the deflagration flame has a diameter of 18.6 m unless the building compartment floor, ceiling or walls constrain the expansion.

Once the deflagration flame becomes constrained by the building the radiating area of the deflagration stops increasing. However, the flame-front continues to advance as a solid wall of flame across the building compartment interior. The flame front velocity is S_f. The increase in radiant flux intensity impinging on a target occupant increases due to the reduction in separation distance due to the flame front travel. Once floor, wall or ceiling constraint is predicted by the deflagration volume calculation, the spreadsheet formulae should be modified for constant radiating area but advance towards the target.

Some references organize the relation used to predict the radiant flux intensity (kW/m^2) impinging on the occupant to include both a "configuration factor", φ, (also called the "view factor") and the $e^{-\mu L}$ optical transmission losses from the Beer-Lambert Law. The received radiant flux intensity can be computed from:[36]

$$q'' = E\varphi e^{-\mu L} \qquad \text{eqn. V.21.}$$

where E = emissive power of deflagration flame, kW/m^2
φ = configuration factor, unitless fractional value
$e^{-\mu L}$ = Beer-Lambert Law atmospheric absorbance, unitless fractional value
q'' = received radiant flux intensity, kW/m^2

The "configuration factor", φ, combines the various geometrical relations into a single factor. It is calculated for the geometric relationship between the radiator and the target. For a rectangular radiator the configuration factor reflects the dimensional designations shown in Figure V.9. Under the scenario with no dust accumulations that can be suspended and cause optical absorbance of the air, the $e^{-\mu L}$ term reduces to 1.

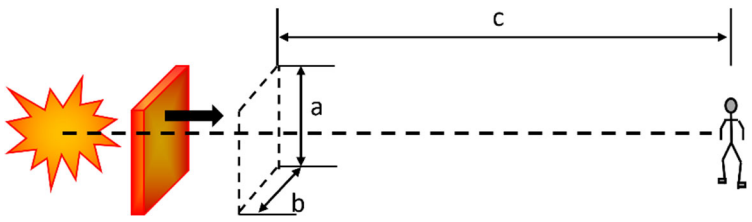


Figure V.9. Parameters for Configuration Factor

For the planar flame front depicted in Figure V.9, the configuration factor, also called "view factor" is computed with:[37]

$$F_{1,2} = 2/\pi \left[\frac{X}{(1+X^2)^{1/2}} \tan^{-1}\left[\frac{Y}{(1+X^2)^{1/2}} \right] + \frac{Y}{(1+Y^2)^{1/2}} \tan^{-1}\left[\frac{X}{(1+Y^2)^{1/2}} \right] \right] \qquad \text{eqn. V.22.}$$

where $X = a/c$ and $Y = b/c$

Once the event becomes constrained by the building structure the expansion of the BCD is determined by the building compartment geometry. This computational estimate is dependent on the specific building compartment dimensions. Furthermore, it is only credible under the following conditions:

1.) there is sufficient vent area in the compartment walls to prevent an increase in pressure ahead of the flame-front in the pre-existing dust suspension,

2.) there is no increase in combustion rate due to turbulence,

To illustrate the process of estimating radiant flux exposure for the purpose of assessing personnel protection needs and options, consider a building compartment as pictured in Figure V.7 that is 30 m wide, 8 m from floor to ceiling and 50 m long. The occupant is located 5 m from an end-wall and the ignition occurs 5 m from the opposite end-wall. The building compartment has dust accumulations on all upward-facing horizontal surfaces in excess of 5 cm deep. The dust is corn starch with MEC = 50 g/m^3 and c_w = 400 g/m^3.

As with the inherently limited deflagration, above, estimating the radiant flux on a target occupant from a BCD involves computing the radiating area of the flame, but in the BCD scenario it is done as a function of time. The rate of flame area increase is proportional the square of the flame speed, S_u, through the dust cloud. S_u can be used to determine the radius of the deflagration flame at increments in time after ignition. This allows the determination of radiating area at each increment in time.

Once an estimate for the flame speed has been developed, one can estimate the radiant flux on a target occupant from a BCD at selected points in time to evaluate protection needs and limitations. This is done as a two-step process. First the radiant flux on the occupant is computed for an unconstrained deflagration until the flame becomes constrained by the ceiling, walls or floor. Once constraint occurs, the calculation is modified to approximate the deflagration as a rectangular sheet of flame occupying the cross-sectional area of the compartment, moving across the compartment long dimension towards the target occupant.
Equation V.9.

$$q'' = X_r (Q\, e^{-\mu L} / 4\pi L^2) \cos\Theta$$

requires a numerical value for Q, the heat release rate. One can use the experimentally derived value of 350 kW/m^2 multiplied by the radiating area for Q as shown in equation V.4., above. When this value is used it already includes the application of the parameter X_r.

In the alternative, Q can be computed from the deflagration flame volume, v_f, at time, t, the dust concentration, c, the net heat of combustion, ΔH_c, a correction for the combustion efficiency, η, and a correction factor for the fraction of the radiant power radiated towards the target. This provides the energy release, H_c, but not the heat release rate, Q. Q is defined as dH/dt but sufficient precision for the purposes of this annex can be had by approximating dH/dt with $\Delta H/\Delta t$ and using the heat release, MJ, as the average heat release rate, MW, for the 1 second time interval centered on the point in time under consideration.

When this calculation is used, the radiant fraction, X_r should be included. Since dust deflagrations are generally fuel-rich, the flame intermediate compounds leave the combustion zone incompletely oxidized, reducing the quantity of heat from the reaction. ΔH_c is for complete combustion in a cone calorimeter, not a diffusion flame through a dust cloud. A correction, η, for combustion efficiency, is added and will have a value less than 1.0. The radiant flux from a deflagration flame is emitted towards the target, the direction opposite to towards the target, to the left, right, up and down, the fraction emitted towards the target is 1/6th the total radiant flux. This leads to the relation:

$$Q = (v_f\, c\, \Delta H_c/\Delta t)(X_r\, \eta)/6 \qquad \text{Eqn. V.23.}$$

where v_f = volume of deflagration flame at time, t
c = dust concentration, kg/m^3
η = combustion efficiency
Δt = 0.5 sec

The following numerical values can be used as initial inputs:

X_r, Radiative Fraction of the heat release. (fractional value)	=	0.35
ΔH_c, Net heat of combustion	=	16.2 MJ/kg
η, combustion efficiency	=	0.9
μ, Beer-Lambert absorbance coefficient	=	0.3
Θ, Angle of hypothetical target plane to flame exposure path	=	90º

The received radiant flux (kW/m^2) on the target occupant can be computed for increments in time. The results are provided for conditions of no atmospheric obscuration (clear air, $\mu = 0$) and conditions of a dust cloud of a material like cornstarch (μ=0.3).

To make the computational simulation more realistic, parameters were adjusted at steps in time. The combustion efficiency, η was adjusted to 0.7 after 0.5 seconds. After 0.5 seconds the deflagration flame volume of the previous increment was subtracted from the flame volume when computing flame volume. This volume was also added to the formula for calculating separation distance to accelerate the flame towards the target. Once the deflagration flame became constrained by the walls, floor and ceiling the radiating area, flame volume and emitted radiant flux were held constant and the increase in received flux intensity is due to the reduction in separation distance.

Time, t sec	Radius, m	Radiating area, m^2	Flame Volume, m^3	Emitted Radiant Flux, MW	Separation distance, m	q" μ=0 kW/m^2	q" μ=0.3 kW/m^2
0.5	2.33	17.0	52.6	5.59	37.7	0.1	<<0.1
1.0	4.65	67.9	368.2	60.9	35.1	8.3	<<0.1
1.5	6.98	152.8	1052.	261.0	31.5	29.6	<<0.1
2.0	NA	240	2315.	766	26.3	93.1	0.1
2.5	NA	240	2315.	766	18.7	184	0.25
3.0	NA	240	2315.	766	16.4	240	0.3
3.5	NA	240	2315.	766	14.1	325	0.4
4.0	NA	240	2315.	766	11.8	466	0.6
4.5	NA	240	2315.	766	9.4	725	1.0
5.0	NA	240	2315.	766	7.1	1,278	1.8
5.5	NA	240	2315.	766	4.8	2,824	3.9
6.0	NA	240	2315.	766	2.5	10,711	14.8
6.5	NA	240	2315.	766	0.1	3.87E6	5.33E3

Table V.3.2.3 Predicted Results of a BCD Event

At the end of the first increment in time, 0.5 seconds after ignition, the incident radiant flux on the target occupant is too small to be noticed due to separation distance. Note that the emitted radiant flux divided by the circular radiating area is 330 kW/m^2, quite close to the 350 kW/m^2 used in equation V.4.

The calculated radiant flux at the target occupant location can be compared to the performance criteria selected in accordance with Section V.2.3 and 2.4 to determine whether FRG is needed to achieve the personnel safety objectives, and, if so, can FRG provide the level of personnel protection needed to achieve that same objective.

Using one of the methods above, one can compute an estimate for the radiant flux intensity impinging on the occupant. The calculated thermal dose can be compared to that associated with the level of tolerable injury. If the thermal dose intensity at the occupant location exceeds the that sufficient to cause 3rd degree burns on unprotected skin third-degree burns are expected to result. Also, if the thermal dose at the occupant location exceeds that sufficient to ignite clothing, 3rd-degree burns are expected to occur due to occupant exposure to burning clothing. In these

examples, the personnel injury limitation objective criterion has been exceeded and fatality is likely. [38] If the estimated thermal flux intensity is determined to be capable of igniting ordinary clothing the use of FRG is necessary. This does not necessarily imply that FRG is capable of achieving the injury prevention objective. There are limits to the thermal protection capabilities of FRG. It only means that FRG can provide a measure of protection that might be sufficient to reduce the severity of burn injuries in some cases. Refer to Section V.4.1 for additional perspective on limitations of the protective capability of FRG.

V.3.2.3. Estimating Deflagration Flame Impingement Hazard

The radiant flux intensity estimate above is based upon modeling the deflagration as occurring rapidly and with a radiating area derived from the pre-ignition dust suspension volume. This allows one to obtain a bounding-value estimate of the radiant flux intensity on a target at a defined separation distance. The radiant flux is modeled as uniformly distributed throughout the dust suspension volume abruptly and as an optically dense radiator having a circular radiating area until it becomes constrained by the building compartment walls, floor and ceiling. In order to rely on a radiant flux model, the assumption that there is no piloted ignition by the deflagration flame should be confirmed.

One method to obtain an estimate for the distance an igniting flame will extend from a deflagration originating in a piece of equipment and directed through an opening such as an open chute at a bag unloading station, is to use the NFPA 68 vented deflagration fireball calculation outlined in Section 6.8.3.[39]_

A second method to obtain an estimate for flame extension for a localized, unconfined dust cloud is to compute the flame volume of the burning cloud by applying the ideal gas law to the experimentally determined P_{max} value for the material. P_{max} is a ratio between the maximum pressure and initial pressure in a constant volume environment, and by the ideal gas law this would be equivalent to the ratio of the final volume to the initial volume for a constant pressure environment, assuming adiabatic boundary conditions and comparable combustion characteristics in the two scenarios. The flame volume expansion factor is simply equated to the numerical value for P_{max}.

A third strategy for obtaining an estimate for the distance an igniting flame will extend from a deflagration can be derived from the combustion chemistry. The deflagration flame volume can be modelled as occupying the entire dust suspension volume at the adiabatic flame temperature and then expanding according to the Ideal Gas Law. The flame temperature is then derived from the combustion chemistry.

A dust deflagration involving non-metallic particulates like plastics, agricultural products, paper and forest products can be approximated by using common corn starch and the chemical equation:

$$C_6H_{10}O_5 + 6\,O_2 \Rightarrow 6\,CO_2 + 5\,H_2O + \text{Heat} \qquad \text{eqn. V.24}$$

Normalizing this stoichiometric equation for 1.0 m^3 of air yields:

$$1.54\ C_6H_{10}O_5 + 9.26\ O_2 + 34.7\ N_2 + 0.63\ Ar \Rightarrow$$
$$9.26\ CO_2 + 7.71\ H_2O + 34.7\ N_2 + 0.63\ Ar + Heat \qquad \text{eqn. V.25.}$$

In addition to the 17.3% volumetric expansion due to the increase in the number of moles of gaseous combustion products, there is the liberated heat that will cause the combustion products gas to expand.

$$(470\ kJ/mole\ O_2)(9.26\ mole\ O_2) = 4{,}352\ kJ\ Heat \quad [40] \qquad \text{eqn. V. 26.}$$

This heat is liberated into the combustion product gas. The resulting temperature of the gas can be computed using:

$$\Delta T = \Delta H/mc_p \qquad \text{eqn. V. 27.}$$

Where ΔH = liberated heat of combustion, 4,343 kJ
m = mass, g
c_p = specific heat, j/mole°K
ΔT = change in temperature, °K

The temperature increase due to the combustion reaction is computed with

$$\Delta T = \Delta H/ (m_{CO2}c_{pCO2} + m_{H2O}c_{pH2O} + m_{N2}c_{pN2} + m_{Ar}c_{pAr}) \qquad \text{eqn. V.28.}$$

Using the following values leads to a computed temperature increase for the reaction normalized to 1.0 m^3 in volume. For this example, we used values for c_p at 1200 ºK as an average probable flame temperature.

Gas	CO_2	H_2O	N_2	Ar
Mass, g/m^3	401	139	972	25.2
c_p @ 1200 °K[41], j/g°K	1.28	2.43	1.24	0.523

ΔT = 2097. 6 °K

If the reaction occurred at a 300 °K ambient temperature, the deflagration flame temperature is estimated to be approximately 2,397 °K. This combustion temperature is derived from the chemical equation of the combustion of starch. Due to the similarity of the chemical compounds constituting wood, cellulosic and other agricultural products similar results can be expected for those particulates. However, since this estimate assumes complete, stoichiometric combustion and does not take into account endothermic pyrolytic processes the user should select a reasonable bounding value for the temperature estimate. Furthermore, the chemical equation used here does not reflect the combustion of a metallic fuel. For metallic fuels an explicit chemical equation for the specific fuel should be used.

As the combustion product gas expands against the ambient air it cools. The resulting temperature as a function of distance from the initial dust suspension surface can be computed by using the Ideal Gas Law relation

$$P_1V_1/n_1RT_1 = P_2V_2/n_2RT_2 \qquad \text{eqn. V.29.}$$

Where the "1" subscripts refer to the initial deflagration at ignition and the "2" subscripts refer to the post expansion conditions. This relation assumes ideal conditions and that the expanding deflagration product gas expands without mixing with ambient air. Since mixing with cool ambient air results in a mixture of lower temperature, mixing does not expand the distance at which hazardous temperatures exist.

This relationship allows us to compute the volume occupied by the deflagration product gases when they have expanded and cooled to the temperature used for the life-safety criteria derived from the objectives.

Since the ignition of ordinary street clothing made of cotton and polyester fabrics has been widely studied. Ignition onset has been reported by some researchers when "ordinary clothing" is exposed to radiant flux on the order of 50 kW/m^2. Other research reports the onset of ignition when temperatures of 200 to 300°C (473 to 573 °K) are attained. These criteria can be used establish the minimum separation distance between the initial, pre-ignition dust suspension and the target personnel when the ignition of clothing by a piloted ignition of clothing by the deflagration flame is the safety criterion. [42, 43]

Using the values for starch as a surrogate for the combustible dust in the hazard area, the deflagration flame will cease to be sufficiently hot to ignite clothing when the gas volume has increased by a factor of 5 to 4.2, depending upon the ignition characteristics of the clothing involved. As long as personnel are reliably prevented from being closer to the surface of the deflagration flame than the diameter attained when the temperature has decreased to the applicable ignition temperature the combustion product gases would not be expected to ignite clothing.

This applicability of the result is limited by the assumptions regarding the combustion event. First and foremost, it assumes there is no entrained dust in the effluent combustion product

gases. Is this a credible assumption? Any entrained dust will burn once it is exposed to fresh air at the flame/ambient interface. This calculation does not account for this. Entrained dust is expected to extend the flame front further than the calculation suggests. Second, this value is for the carbon-containing fuels similar to starch. The accuracy of this separation distance estimate can be improved by using the chemical equation for the fuel present in the specific hazard area. However, the uncertainty introduced by the possibility of entrained dust might exceed any improvement in precision attained with a more specific chemical equation. Third, the use of this separation distance estimate method is not applicable to metallic particulate deflagrations due to the differences in the combustion chemistries, the heats of combustion and resulting flame temperatures for metallic particulate deflagrations.

Remain mindful that any calculation of deflagration flame extension is predicated on all of the assumptions that served as the basis for the calculation. Using the "worst-case concentration", c_w, might not produce the largest flame extension volume. A fuel-rich deflagration will probably expel unburned dust beyond the initial dust suspension, where additional combustion air becomes available, extending the flame-front. How far is unknown. When performing a calculation to model flame extension each assumption must be made using values that produce a worst-case estimate. Furthermore, "safety-factors" that address the multiple uncertainties should be applied. Finally, remain mindful that these calculations assume that there are no dust accumulations present in the building compartment that can become suspended, entrained and ignited, thereby adding fuel and extending the flame volume beyond the initial deflagration. If there are dust accumulations in the building compartment interior, transition to a building compartment deflagration should be expected.

V.4. Evaluating Personnel Protection Options

Once the flash-fire scenarios are developed, the thermal flux exposure for each scenario can be computed as a function of the occupant location relative to the epicenter of the initial ignition and expansion of the deflagration flame-front. Relations shown above allow the user to compute the radiant flux intensity (kW/m^2) at the exposed surface of known occupant locations. Those relations can be used to determine if separation distance control can achieve the injury prevention objective. Other relations shown above can be used to predict deflagration flame extension distance. These second relations can be used to determine if piloted ignition by the deflagration flame at a given occupant location is likely.

For those cases where piloted ignition by the deflagration flame is not predicted in the flash-fire scenario, the thermal flux is limited to the radiant flux. The radiant flux intensity that reflects the injury limitation objective can be used to determine if the personnel protection objectives can be achieved with a strategy of controlling separation distance.

In those cases where either piloted ignition by the deflagration flame or radiant flux sufficient to ignite ordinary clothing cannot be precluded, the ignition of ordinary clothing is to be expected. Once an occupant's clothing ignites, fatal burn injury often results. As a consequence, FRG is needed wherever ignition of the occupant's clothing is possible. This does not imply that FRG is

capable of achieving the injury prevention objective. There are limits to the thermal protection capabilities of FRG. It only means that FRG can provide a measure of protection that might be sufficient to reduce the severity of burn injuries in some cases. The analytical methods presented here are not capable of demonstrating that a certain degree of injury can be prevented with the use of FRG in the above scenarios. Consequently, the use of FRG cannot be expected to prevent injury or fatality in the event of a building compartment deflagration.

If a flash-fire resulting from a building compartment deflagration fueled by accumulated fugitive dust is possible, engulfment of occupants is likely. The thermal flux intensities and separation distances between the deflagration flame front and the occupants are both unpredictable but expected to exceed the protective capabilities of FRG. FRG should not be relied upon to achieve a personnel protection objective. The use of FRG can contribute some reduction of the severity and probability of injuries when the fire event does not attain the worst-case severity but there is also the possibility that it will not. Consequently, the dust accumulations should be eliminated and the facility interior maintained below the dust accumulation levels that allow a building compartment deflagration to occur. See Section 8.4 and associated Annex material. Annex S provides information on assessing dust accumulation to address the potential for a BCD.

V.4.1 Limitation on the Reliance on FRG

The stated intent of FRG under NFPA 2112 is "not contributing to the burn injury of the wearer, providing a degree of protection to the wearer, and reducing the severity of burn injuries resulting during egress from or accidental exposure to short-duration thermal exposure."[44] NFPA 2112 states that garments shall be tested in accordance with the standard and shall result in an average predicted body burn of not more than 50 percent with no single burn being equal to or greater than 55 percent based on the total surface area covered by sensors, excluding hands and feet. This standard does not state how severe the burns are permitted to be. Third degree burns over 50% of the body are usually taken to be fatal.[45]

NFPA 2113 states: "Flame-resistant garments can reduce the severity of burn injury as a result of a fire but cannot completely prevent an injury." [46] NFPA 2113 uses a pass/fail test criterion of a thermal dose of 252 kJ/m^2 (84 kW/m^2 for 3.0 seconds) applied to the garment.[47] The pass/fail test criterion is used to indicate whether or not the computer model used for the testing indicates that the garment would allow more than 50 percent burns overall or a single burn being equal to or greater than 55 percent based on the total surface area covered by sensors. But it does not provide information regarding the effect this thermal dose will have on the user of the FRG. NFPA 2112 also uses the 84. kW/m^2 radiant flux for 3 seconds, conducted in accordance with ASTM F 1930, for the full body acceptance test.[48]

FRG is tested in accordance with ASTM F 1930 ***Standard Test Method for Evaluation of Flame Resistant Clothing for Protection Against Flash Fire Simulations Using an Instrumented Manikin***.[49] The test uses multiple propane burners with flame adjusted to produce a yellow-to-red flame.[50] A manikin equipped with a minimum of 100 thermal sensors attached to and located across its exterior surface is clothed in the FRG under test and exposed to the burners for a set time.[51]

The thermal energy sensors generate data from which the heat flux at the skin at each sensor location and its variation with time can be calculated. The time/temperature history data for the sensors is recorded. This data is used to compute the time/temperature exposure of the manikin and the severity of the burn injury to a human wearing the manikin is computed from a burn injury model.[52]

The model computes the rate of increase of burn injury factor, $d\Omega/dt$, from the relation:[53]

$$d\Omega/dt = P \exp(-\Delta E/RT) \qquad \text{eqn. V. 30.}$$

where $d\Omega/dt$ = rate of increase in the burn injury factor, Ω, per unit time
T = epidermal skin temperature, °K
R = Ideal Gas Constant, 8.314 kJ/kmole°K
P = experimentally derived factor, sec^{-1}
ΔE = experimentally derived activation energy, kJ/kmole
t = time duration the skin temperature exceeds 44°C (317.2 °K)

The accumulated skin damage is computed by integrating the relation to obtain:[54]

$$\Omega = \int_0^t P \exp(-\Delta E/RT)\, dt \qquad \text{eqn. V. 31.}$$

Second-degree burn injury is predicted when the magnitude of $\Omega \leq 1.0$ at the dermis/epidermis interface depth and third-degree burns are predicted for magnitudes of $\Omega \geq 1.0$ at the dermis/subcutaneous (adipose) tissue interface depth.

The computer model computes the value of Ω as a function of location on the body and assigns an injury severity for that fraction of the body area. The injury-area products are then combined to yield a prediction of the percent body area with 2nd-degree burns and the percentage of body area with 3rd-degree burns to the wearer's body.[55] The acceptance criterion is less than 50% of the body surface receiving 2nd- or 3rd-degree burn jury.[56] The user can conclude that a thermal dose of 252 kJ/m^2 will likely lead to 2nd- and 3rd-degree burns over up to 50% of the wearer's body surface.

A simplified example in the CCPS Guidelines for Chemical Process Quantitative Risk Analysis 2nd Edition, predicts a 50% probability of fatality for a thermal flux of 85.2 kW/m^2 for an exposure time of 10 seconds.[57] The thermal flux value differs from the 84 kW/m^2 thermal flux referenced in NFPA 2112. Additionally, 3 second exposure time referenced in A.4.3 of NFPA 2113 is much shorter than the 10 second exposure duration used by CCPS.

The CCPS estimate is obtained by using probit equations. (A probit function is a mathematical operation on a Gaussian probability distribution that converts a dose-response curve into an approximately straight line.) Probit equations for the probit variable, Y, are based upon a causative variable, V, and at least two constants, k_1 and k_2, using an equation of the form:

$$Y = k_1 + k_2 \ln V \qquad \text{eqn. V. 32.}$$

The probits (probability units) are converted into percentages using a table.[58] The probit equation is used to determine the thermal flux intensity that is expected to result in 3rd-degree burns over 50% of the body from an exposure of given duration. This reference reports that the probit equations are contemplating "lightly clothed" occupants.[59] No quantitative relation is provided for occupants equipped with FRG.

V.5. Summary of Hazard Management Strategy Development

V.5.1 Establish Objectives for Personnel Safety

The first step in assessing the workplace hazard management is establishing clear objectives for personnel safety. The facility operator should document its personnel safety objectives.

V.5.2 Establish Clear Performance Criteria

The personnel safety objectives should be used to establish clear performance criteria. The performance criteria should be measurable and expressed quantitatively. The facility operator should document its personnel safety performance criteria.

Examples of values for various criteria for unprotected occupants are:[60]

Pain threshold :	41.9 kJ/m^2
Blister, severe 2nd-degree burn:	83.8 kJ/m^2
Severe 3rd-degree burn:	162.5 kJ/m^2
Performance Criterion for FRG	252 kJ/m^2 [61]

V.5.3 Identify Flash Fire Hazard Areas

All locations in the dust-handling building compartment that can support a dust deflagration and pose a flash-fire hazard to the occupants should be identified. The facility operator should document the deflagration and flash-fire hazards.

It has been mentioned above that once an occupant's clothing ignites, the resulting injury is usually fatal third-degree burns. The available technology is the use of FRG for employees exposed to the potential for the ignition of their clothing. The workplace hazard assessment first identifies those areas within the facility where employees are exposed to the potential of clothing ignition and where they are not. Those areas where employees are exposed to the potential of clothing ignition from flash-fires are identified as areas where FRG use should be required.

V.5.4 Determine Radiant Heat Flux Exposures

The radiant flux that would impinge upon an occupant located at the nearest location to the deflagration epicenter should be computed for each flash-fire scenario.

V. 5.5 Determine Where Each Level of Personnel Protection Is Both Necessary and Sufficient

If the calculated radiant flux exceeds the criteria **selected by the facility operator** for personnel injury prevention, the affected employees should be equipped to preclude injury.

5.5.1 Where the predicted radiant flux in an occupiable location is sufficient to cause ignition of ordinary clothing that location should be identified as requiring FRG use.

5.5.2 Employees permitted to occupy locations where FRG is required should be equipped with FRG designed in accordance with NFPA 2112 and used in accordance with NFPA 2113.

5.5.3 Employees should not be permitted to occupy locations where the predicted radiant flux intensity exceeds the performance criteria of the FRG.

5.5.4 Protection should be provided for the body as well as the head, face and hands.

V.5.6 Determine Where Flames Could Engulf Occupants

The maximum deflagration flame extension distance should be computed for each flash-fire scenario.

If the calculated flame extension distance exceeds the minimum applicable personnel separation from the deflagration epicenter, affected employees should be equipped with FRG designed in accordance with NFPA 2112 and used in accordance with NFPA 2113.

Protection should be provided for the head, face, and hands as well as the body.

Flame impingement should be expected to lead to the ignition of ordinary clothing. Clothing ignition is expected to lead to severe 3rd-degree burns and fatality.[62]

V.5.7 Consider Limitations of Protective Capability of FRG

It has been mentioned above that once an occupant's clothing ignites, the resulting injury is usually fatal third-degree burns. The available technology is the use of FRG for employees exposed to the potential for the ignition of their clothing. The workplace hazard assessment in V.5.3 first identifies those areas within the facility where a flash fire potential exists.

Those areas where employees are exposed to the potential of clothing ignition from flash-fires are identified as areas where FRG use should be required. However, FRG should not be expected to prevent injury to occupants located in building compartments with fugitive dust accumulations in excess of the Threshold Housekeeping Levels stipulated in this standard (i.e., where there is a likely potential for a BCD).

Furthermore, FRG does not address the injurious effects of inhaling hot combustion product gases from a deflagration. Airway searing can result in pulmonary failure. Combustion product gases are typically comprised of toxic chemical compounds including carbon monoxide, formic acid, formaldehyde, and metal carbonyls where metallic particulates are involved.

Notwithstanding the finite thermal protective capabilities of FRG, it still may be wise to use it as a safeguard, for those situations where the worst-case exposures do not occur, as long as it is recognized FRG might not be capable of preventing injuries in all cases.

REFERENCES

[1] TNO The Netherlands Organization of Applied Scientific Research, ***Methods for the Determination of Possible Damage***, CPR 16E, Director General of Labor, The Hague, The Netherlands, 1992, pg. 8, 12, Table 2.1 "TNO Green Book"

[2] Babrauskas, Vytenis, PhD, ***The Ignition Handbook***, Fire Science Publishers, Issaquah, WA 2003, pg. 816, 822

[3] TNO The Netherlands Organization of Applied Scientific Research, ***Methods for the Determination of Possible Damage***, CPR 16E, Director General of Labor, The Hague, The Netherlands, 1992, pg. 25. "TNO Green Book"

[4] Howel, Menguc, Daun & Siegel, ***Thermal Radiation Heat Transfer***, 7th Edition, CRC Press, Boca Raton, FL, 2021, pg. 140

[5] The SFPE Task Group on Engineering Practices, ***Predicting 1st and 2nd Degree Skin Burns from Thermal Radiation***, Society of Fire Protection Engineers, Bethesda, MD, 2000, pg.18.

[6] The SFPE Task Group on Engineering Practices, ***Predicting 1st and 2nd Degree Skin Burns from Thermal Radiation***, Society of Fire Protection Engineers, Bethesda, MD, 2000, pg.8.

[7] Hurley, Morgan, P.E., FSFPE, Editor-in-Chief, ***The SFPE Handbook of Fire Protection Engineering***, 5th Edition, Springer Science+Business Media, New York, 2016, pg. 2720.

[8] Hurley, Morgan J., P.E. Editor-in-Chief, ***The SFPE Handbook of Fire Protection Engineering***, 5th Edition, Springer, NY, 2016, pg. 2723.

[9] Hurley, Morgan J., P.E. Editor-in-Chief, ***The SFPE Handbook of Fire Protection Engineering***, 5th Edition, Springer, NY, 2016, pg. 2723.

[10] Hurley, Morgan, P.E., FSFPE, Editor-in-Chief, ***The SFPE Handbook of Fire Protection Engineering***, 5th Edition, Springer Science+Business Media, New York, 2016, Chapters 66 & 67.

[11] Section 17.8 NFPA 72, National Fire Alarm and Signaling Systems Code, 2025 Edition, National Fire Protection Association, Quincy, MA 2025.

[12] Drysdale, Dougal, ***An Introduction to Fire Dynamics***, 3rd Edition, John Wiley & Sons, West Sussex, UK, 2011, pgs. 165-169.

[13] Hurley, Morgan, P.E., FSFPE, Editor-in-Chief, ***The SFPE Handbook of Fire Protection Engineering***, 5th Edition, Springer Science+Business Media, New York, 2016, pg. 2654.

[14] Hurley, Morgan J., P.E. Editor-in-Chief, ***The SFPE Handbook of Fire Protection Engineering***, 5th Edition, Springer, NY, 2016, pg.2654.

[15] Hurley, Morgan J., P.E. Editor-in-Chief, ***The SFPE Handbook of Fire Protection Engineering***, 5th Edition, Springer, NY, 2016, pg.2654.

[16] Beyler, C., "Fire Hazard Calculations for Large, Open Hydrocarbon Fires," in SFPE Handbook 5th Edition, Chapter 66, Hurley. M. Editor-in-Chief, Springer, New York, NY. 2016.

[17] Hurley, Morgan, P.E., FSFPE, Editor-in-Chief, ***The SFPE Handbook of Fire Protection Engineering***, 5th Edition, Springer Science+Business Media, New York, 2016, pg. 2655.

[18] CCPS, ***Guidelines for Chemical Process Quantitative Risk Analysis***, 2nd Edition, Center for Chemical Process Safety, American Institute of Chemical Engineers, New York, NY, 2000, Pg. 209.

[19] Hurley, Morgan, P.E., FSFPE, Editor-in-Chief, ***The SFPE Handbook of Fire Protection Engineering***, 5th Edition, Springer Science+Business Media, New York, 2016, pg.2655.

[20] Beyler, C., "Fire Hazard Calculations for Large, Open Hydrocarbon Fires," in SFPE Handbook 5th Edition, Chapter 66, Hurley. M. Editor-in-Chief, Springer, New York, NY. 2016, pg. 2654 et seq..

[21] Siegel & Howell, pg.1035, App C.

[22] Drysdale, Dougal, ***Introduction to Fire Dynamics***, 2nd Ed., John Wiley & Sons, New York, NY, 2011, pgs.37 et seq.

[23] Drysdale, Dougal, ***Introduction to Fire Dynamics***, 2nd Ed., John Wiley & Sons, New York, NY, 2011, pgs. 77, 129, 148-149

[24] Cashdollar, Kenneth and Zlochower, Isaac, **Explosion Temperatures of Metals and Other Elemental Dust Clouds**, Pittsburg Research Laboratory, National Institute for Occupational Safety and Health, https://stacks.cdc.go>cdc>cdc_8762_DS1-4.pdf

[25] Hurley, Morgan, P.E., FSFPE, Editor-in-Chief, ***The SFPE Handbook of Fire Protection Engineering***, 5th Edition, Springer Science+Business Media, New York, 2016, Table A.33, pg. 3449

[26] Zalosh, Robert G. Phd, P.E., ***Industrial Fire Protection Engineering,*** John Wiley & Sons, Ltd., West Sussex PO19 8SQ United Kingdom, 2003, pg. 337-346.

[27] Rockwell, Scott R. "Influence on Coal Dust on Pre-Mixed Turbulent Methane-Air Flames", Doctoral Dissertation Worcester Polytechnic Institute, 2012, pg. 17.

[28] Castellan, Gilbert W., ***Physical Chemistry***, Addison-Wesley Publishing Co., Reading, MA, 1964, pg. 664.

[29] Howel, Menguc, Daun & Siegel, ***Thermal Radiation Heat Transfer***, 7th Edition, CRC Press, Boca Raton, FL, 2021, pg. 37.

[30] Eckhoff, Rolf K. ***Dust Explosions in the Process Industries***, 3rd Ed., Gulf Professional Publishing, Elsevier, Burlington, MA, 2003, pg.9.

[31] Rockwell, Scott R. "Influence on Coal Dust on Pre-Mixed Turbulent Methane-Air Flames", Doctoral Dissertation Worcester Polytechnic Institute, 2012, pg. 17.

[32] Eckhoff, Rolf K. ***Dust Explosions in the Process Industries***, 3rd Ed., Gulf Professional Publishing, Elsevier, Burlington, MA, 2003, pg 271

[33] Ibid

[34] Ibid

[35] Eckhoff, Rolf K. ***Dust Explosions in the Process Industries***, 3rd Ed., Gulf Professional Publishing, Elsevier, Burlington, MA, 2003, pg. 281.

[36] Zalosh, Robert G., PhD, P.E., Industrial Fire Protection Engineering, John Wiley & Sons, West Sussex PO19 8SQ England, 2003, pg. 342.

[37] Zalosh, Robert G., PhD, P.E., Industrial Fire Protection Engineering, John Wiley & Sons, West Sussex PO19 8SQ England, 2003, pg. 343

[38] TNO Green Book, pg. 25.

[39] Section 6.8.3, NFPA 68-2023, Standard onExplosion Protection by Deflagration Venting, 2023 Edition, National Fire Protection Association, Quincy, MA 2023.

[40] Eckhoff, Rolf K. ***Dust Explosions in the Process Industries***, 3rd Ed., Gulf Professional Publishing, Elsevier, Burlington, MA, 2003, pg.6.

[41] https://www.engineeringtoolbox.com/html

[42] Babrauskas, Vytenis, PhD, ***The Ignition Handbook***, Fire Science Publishers, Issaquah, WA 2003, pg. 816, 822

[43] TNO Green Book, pg. 25.

[44] Section 1.2.1, NFPA 2112, ***Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire,*** 2023 Edition, National Fire Protection Association, Quincy, MA 2023.

[45] TNO Green Book, pg. 25.

[46] Section A4.3. NFPA 2113-2025, ***Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire***, 2025 Edition, National Fire Protection Association, Quincy, MA 2025.

[47] Section A.4.3, NFPA 2113-2025, ***Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire***, 2025 Edition, National Fire Protection Association, Quincy, MA 2025.

[48] Section 8.5.6.1, **Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire, 2023 Edition,** National Fire Protection Association, Quincy, MA 2022

[49] Lovasic, Susan L and Neal, Thomas E., PhD, ***Industrial Flash Fire and Burn Injury Fundamentals with an Instrumented Manikin Demonstration of Protective Clothing Performance.*** ASSE Professional Development Conference and Exposition, 2002.

[50] Section 6.7.3.1, ASTM F1930, 2018, ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

[51] Section 6.2.2, ASTM F1930, 2018 ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

[52] Section 6.5.3.1, ASTM F1930, 2018, ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

[53] Section X1.4 ASTM F1930, 2018, ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

[54] Section X1.5 ASTM F1930, 2018, ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

[55] Section 13.5, ASTM F1930, 2018, ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

[56] Section 7.1.5, NFPA 2112 **Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire, 2023 Edition,** National Fire Protection Association, Quincy, MA 2022

[57] CCPS, ***Guidelines for Chemical Process Quantitative Risk Analysis***, 2nd Edition, Center for Chemical Process Safety, American Institute of Chemical Engineers, New York, NY, 2000, pg. 246.

[58] CCPS, ***Guidelines for Chemical Process Quantitative Risk Analysis***, 2nd Edition, Center for Chemical Process Safety, American Institute of Chemical Engineers, New York, NY, 2000, pg. 247.

[59] CCPS, ***Guidelines for Chemical Process Quantitative Risk Analysis***, 2nd Edition, Center for Chemical Process Safety, American Institute of Chemical Engineers, New York, NY, 2000, pg. 270.

[60] The SFPE Task Group on Engineering Practices, ***Predicting 1st and 2nd Degree Skin Burns from Thermal Radiation***, Society of Fire Protection Engineers, Bethesda, MD, 2000, pg.18.

[61] Section A4.3, NFPA2113, NFPA 2113-2025, ***Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire***, 2025 Edition, National Fire Protection Association, Quincy, MA 2025.

[62] TNO The Netherlands Organization of Applied Scientific Research, ***Methods for the Determination of Possible Damage***, CPR 16E, Director General of Labor, The Hague, The Netherlands, 1992, pg. 8, 12, Table 2.1 "TNO Green Book"