Dust Hazard Assessments

Presented by:

Dr. Ashok Ghose Dastidar, PhD MBA
Fellow Engineer – Westinghouse Electric Company
Vice President, Dust & Flammability Testing and Consulting Services

Biography

- B.Sc. Chemistry – Dalhousie University
- MBA – Saint Mary's University
- Master of Applied Science – Technical University of Nova Scotia
- Ph.D. Chemical Engineering– Dalhousie University

- 29 years research in the field of dust & gas/vapor explosions
- Safety Consulting Engineers, Inc. 2001–2007
- Fauske & Associates, LLC 2007–

- Memberships – AIChE, ASTM, NFPA
- Editorial Advisory Board of Powder/Bulk Solids and Journal of Loss Prevention in the Process Industries
- Chairperson of the ASTM E27 Committee on Hazard Potential of Chemicals
- Chairperson of the ASTM E27.05 Subcommittee on Dust Explosion Test Methods
- NFPA Technical Committee 61, 664, & 484
- Chairperson of NFPA 654, 655 and 91

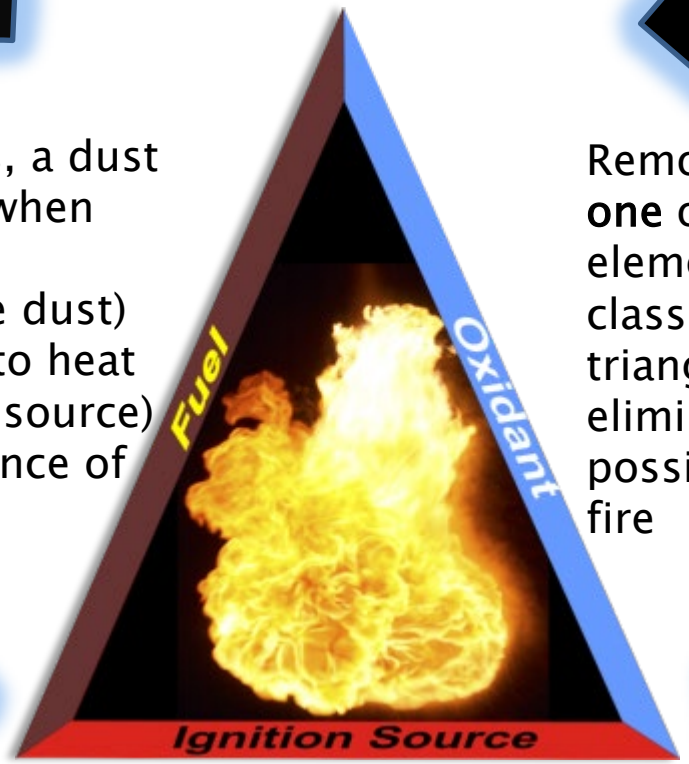
Course Agenda

- Fundamentals of Dust Explosions
- Fundamentals of Characterizing the Explosive Properties of Dusts
- Overview of NFPA 652
- Introduction to Dust Hazard Analysis
- Questions and answers

Fundamentals of Dust Explosions

Dust Fires & Explosions

Like all fires, a dust fire occurs when fuel (the combustible dust) is exposed to heat (an ignition source) in the presence of oxygen (air)



Removing **any one** of these elements of the classic fire triangle eliminates the possibility of a fire

Dust Fires & Explosions (continued)

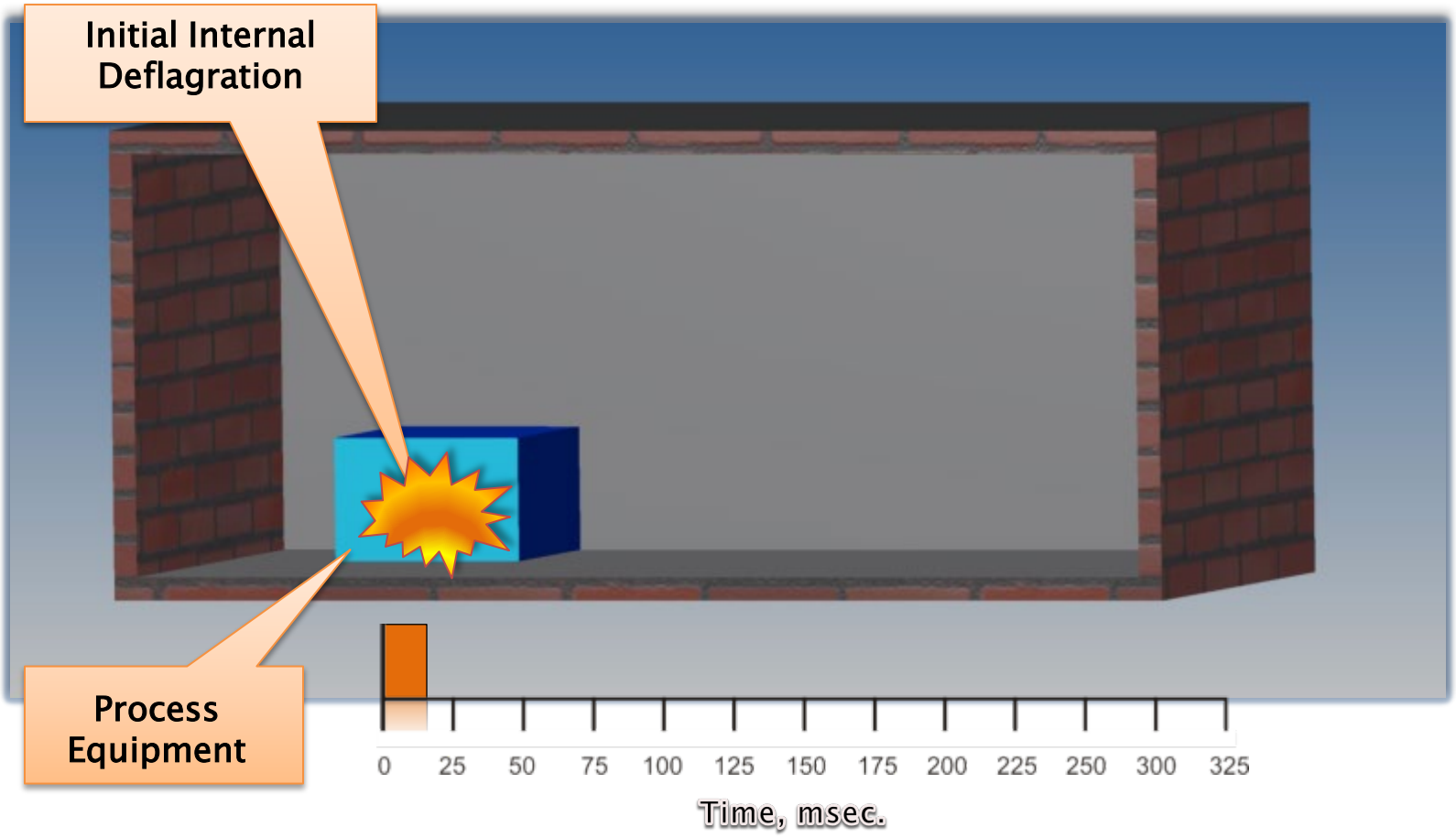
Dust explosions require the presence of two additional elements – *dust dispersion and confinement*

Suspended dust burns more rapidly and confinement allows for pressure buildup; removal of either the suspension or the confinement elements prevents an explosion, although a fire may still occur

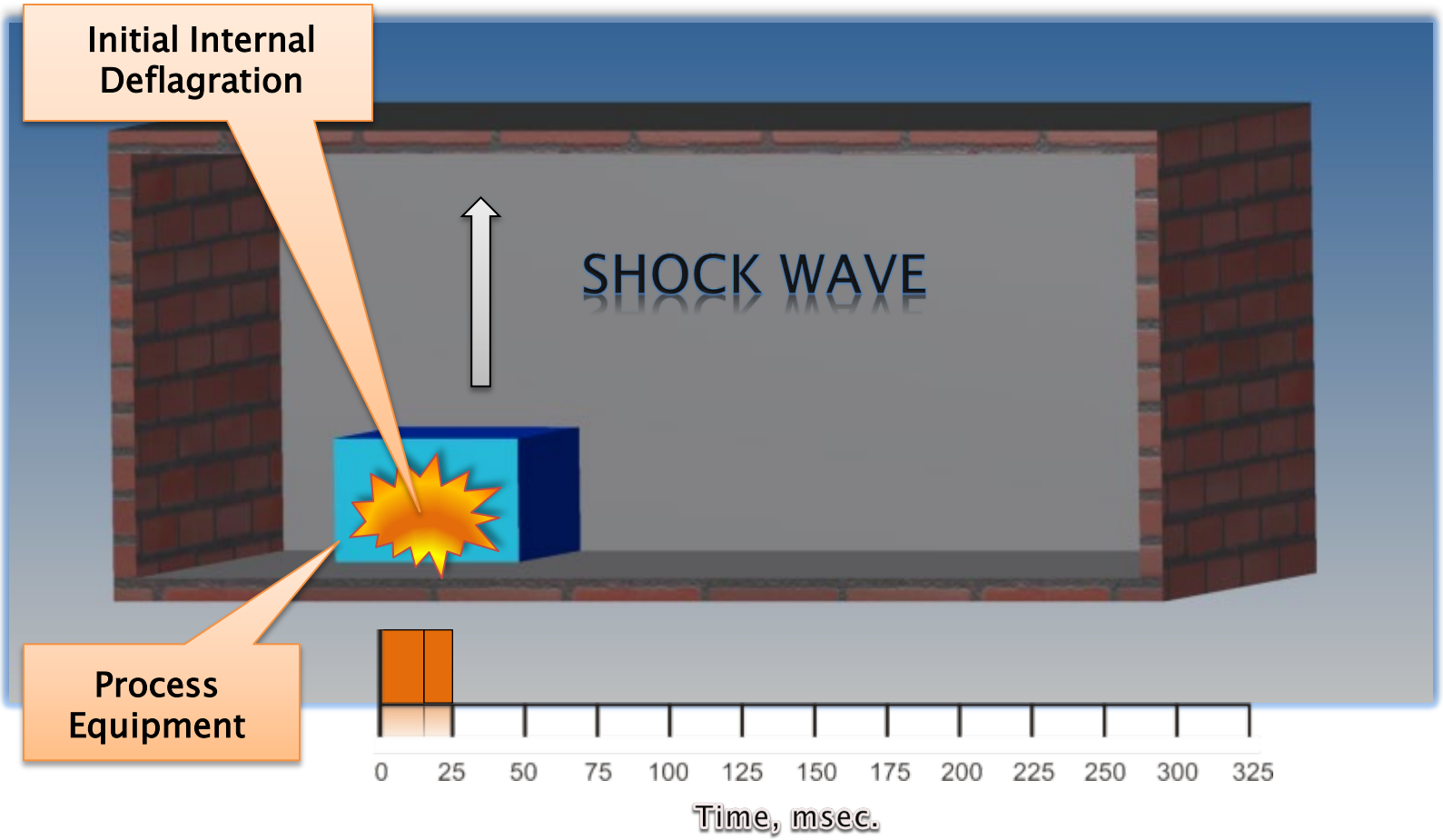
Explosion Types

- **Primary explosion** – usually in process equipment
- A primary dust explosion occurs when a dust suspension within a container, room or piece of equipment is ignited and explodes
- A secondary explosion occurs when dust accumulated on floors or other surfaces is lifted into the air and ignited by the primary explosion

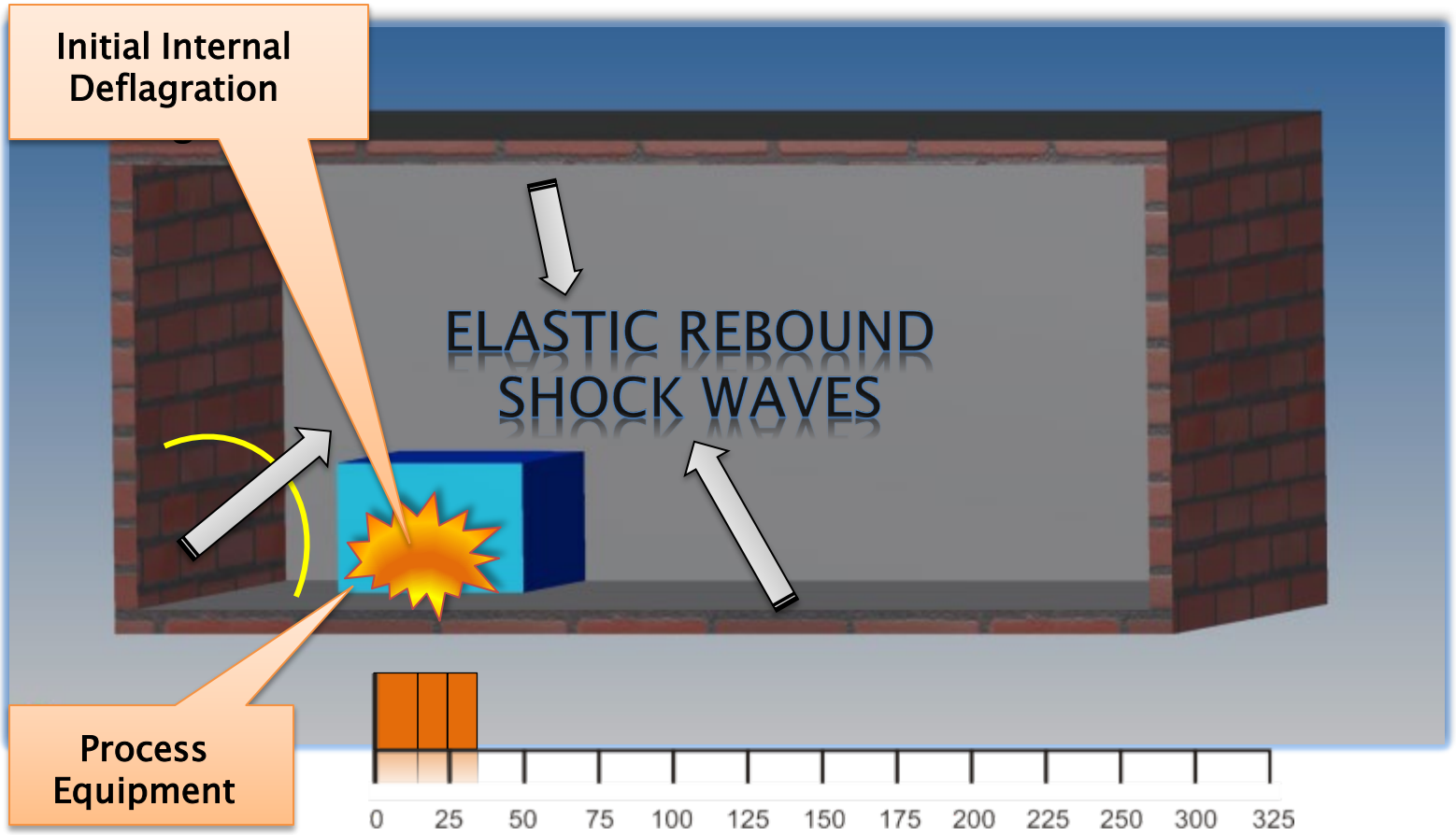
The "Typical" Explosion Event



The "Typical" Explosion Event
(continued)



The "Typical" Explosion Event
(continued)



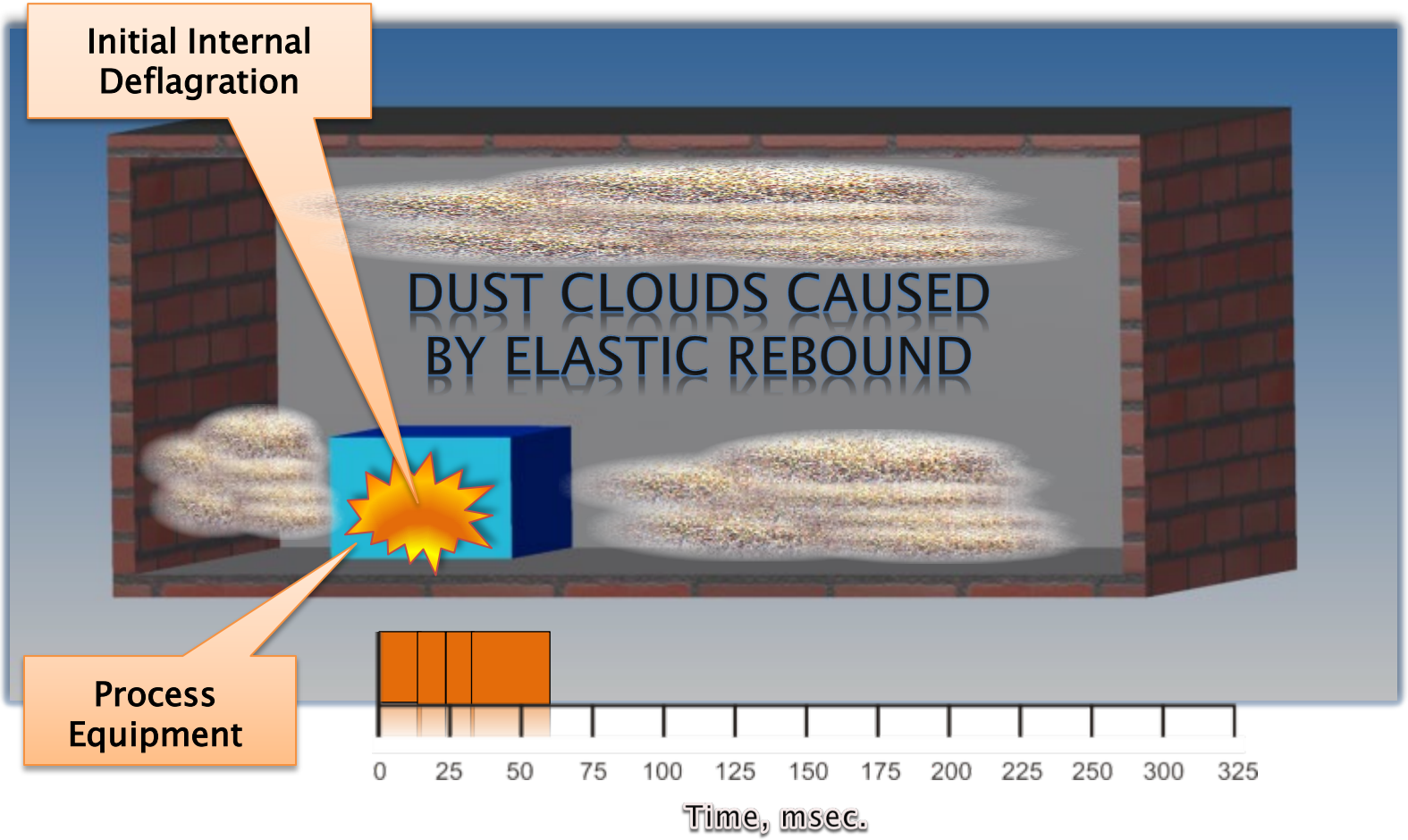
Fugitive Dust Buildup

Source: Hughes Environmental

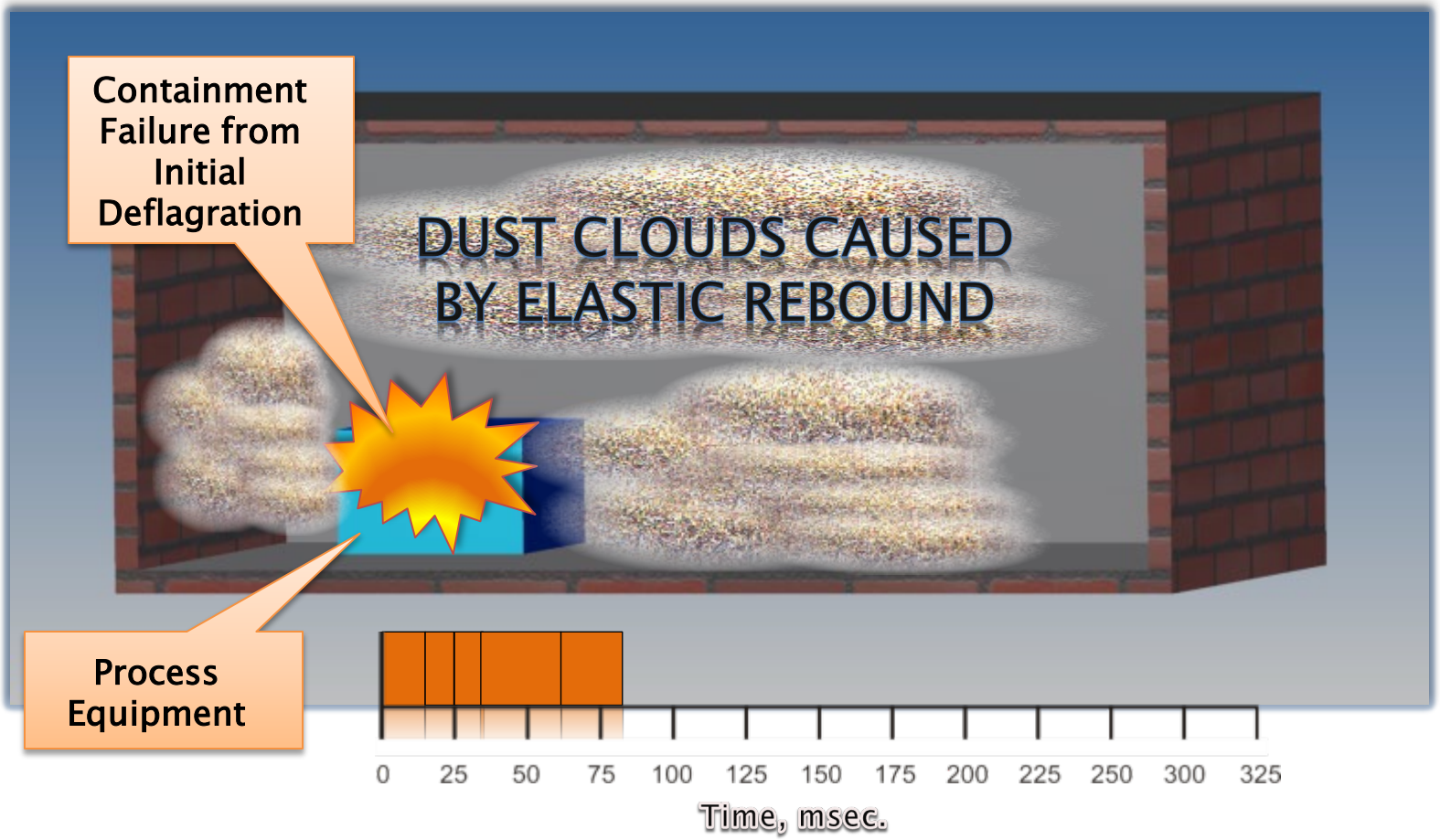
Fugitive Dust Buildup

Source: Hughes Environmental

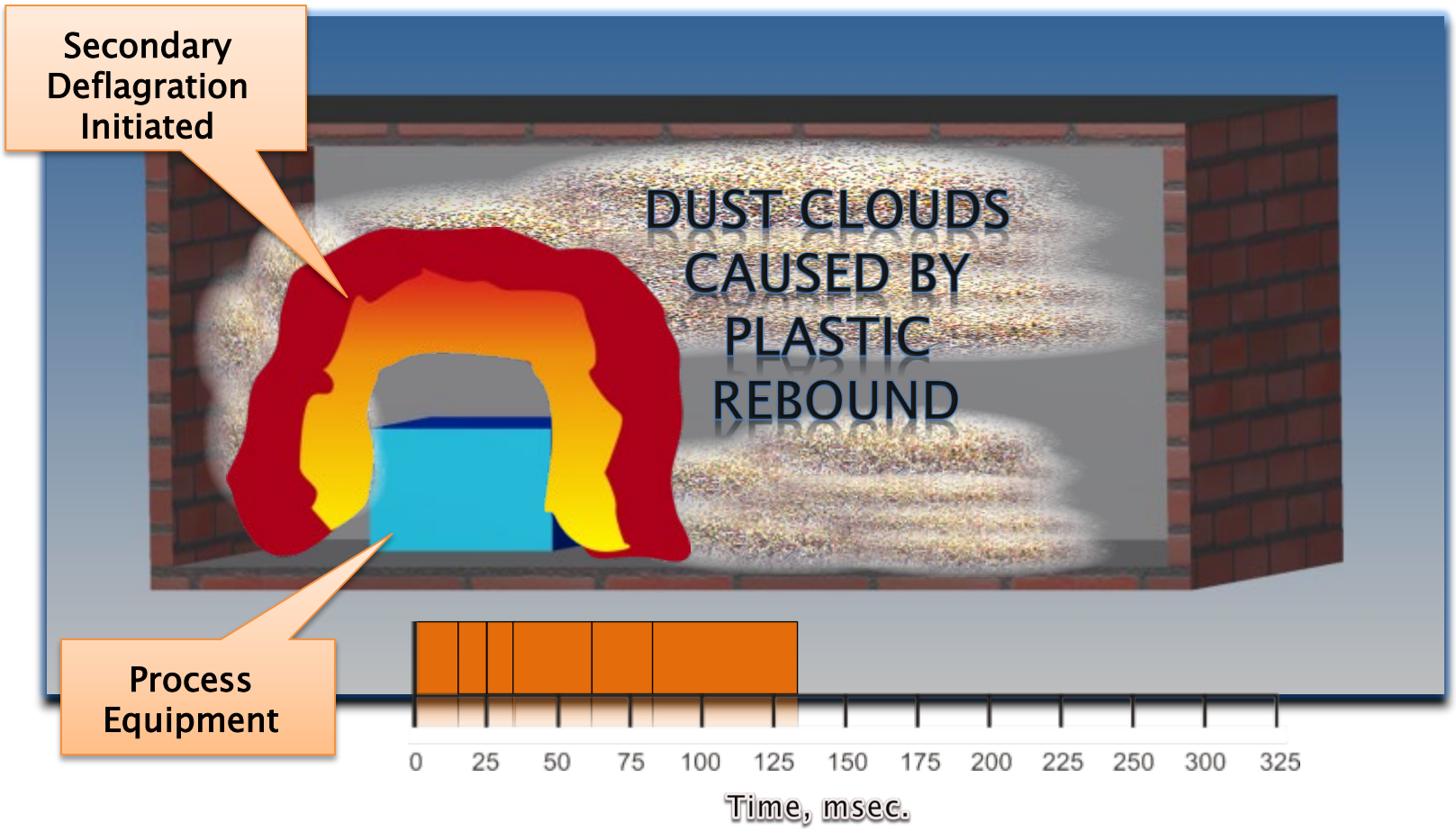
The "Typical" Explosion Event
(continued)



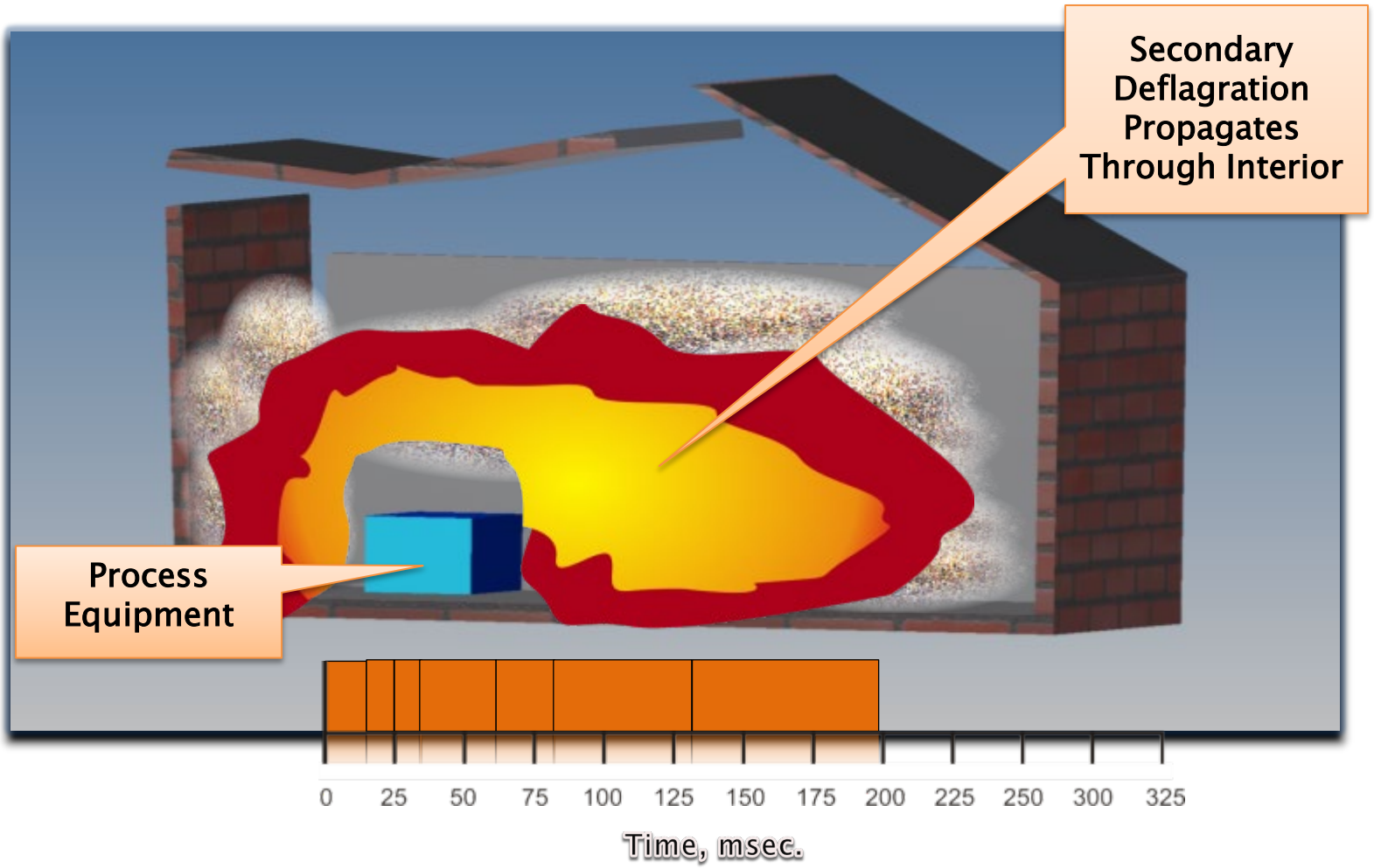
The "Typical" Explosion Event
(continued)



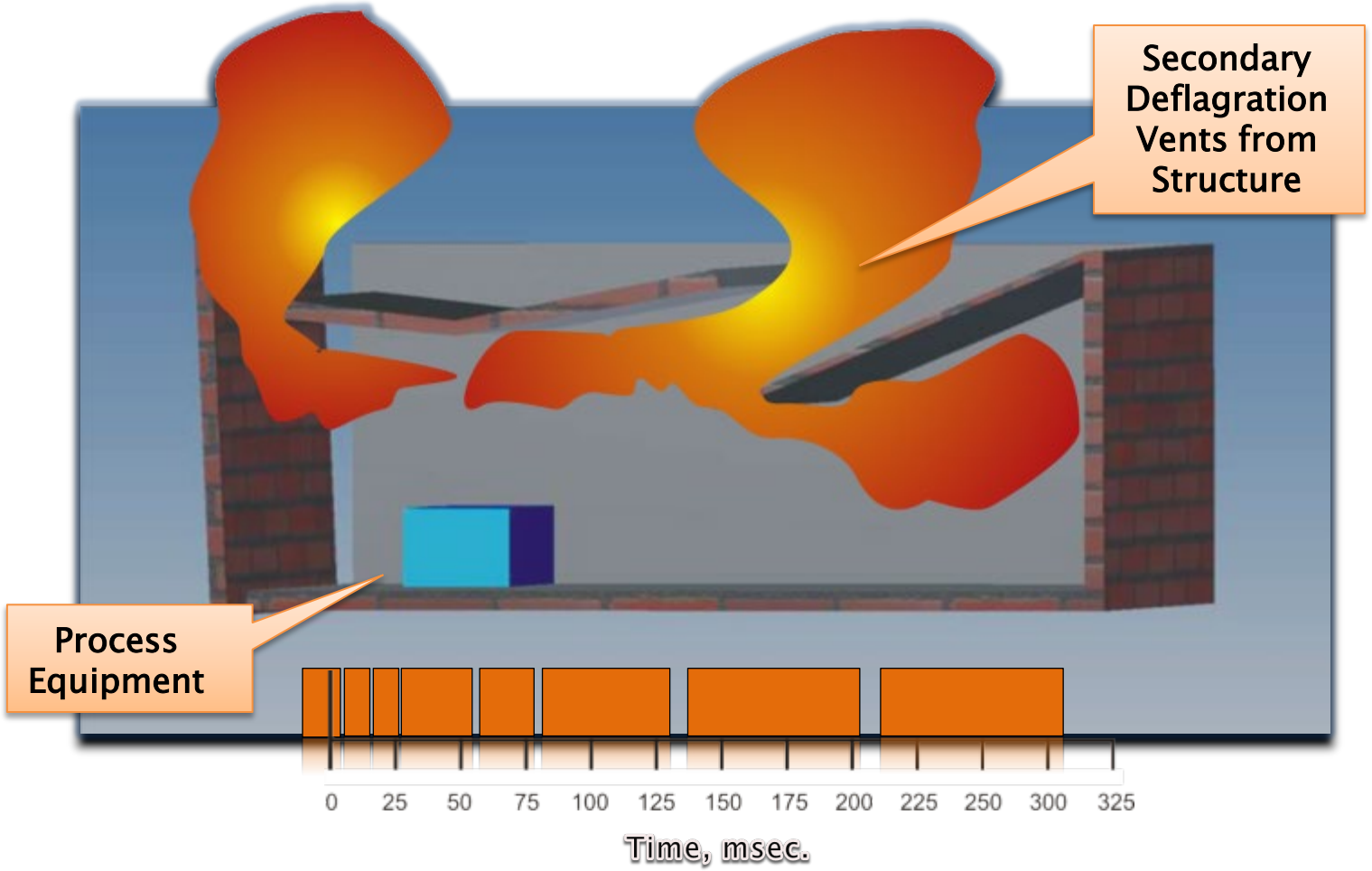
The "Typical" Explosion Event
(continued)



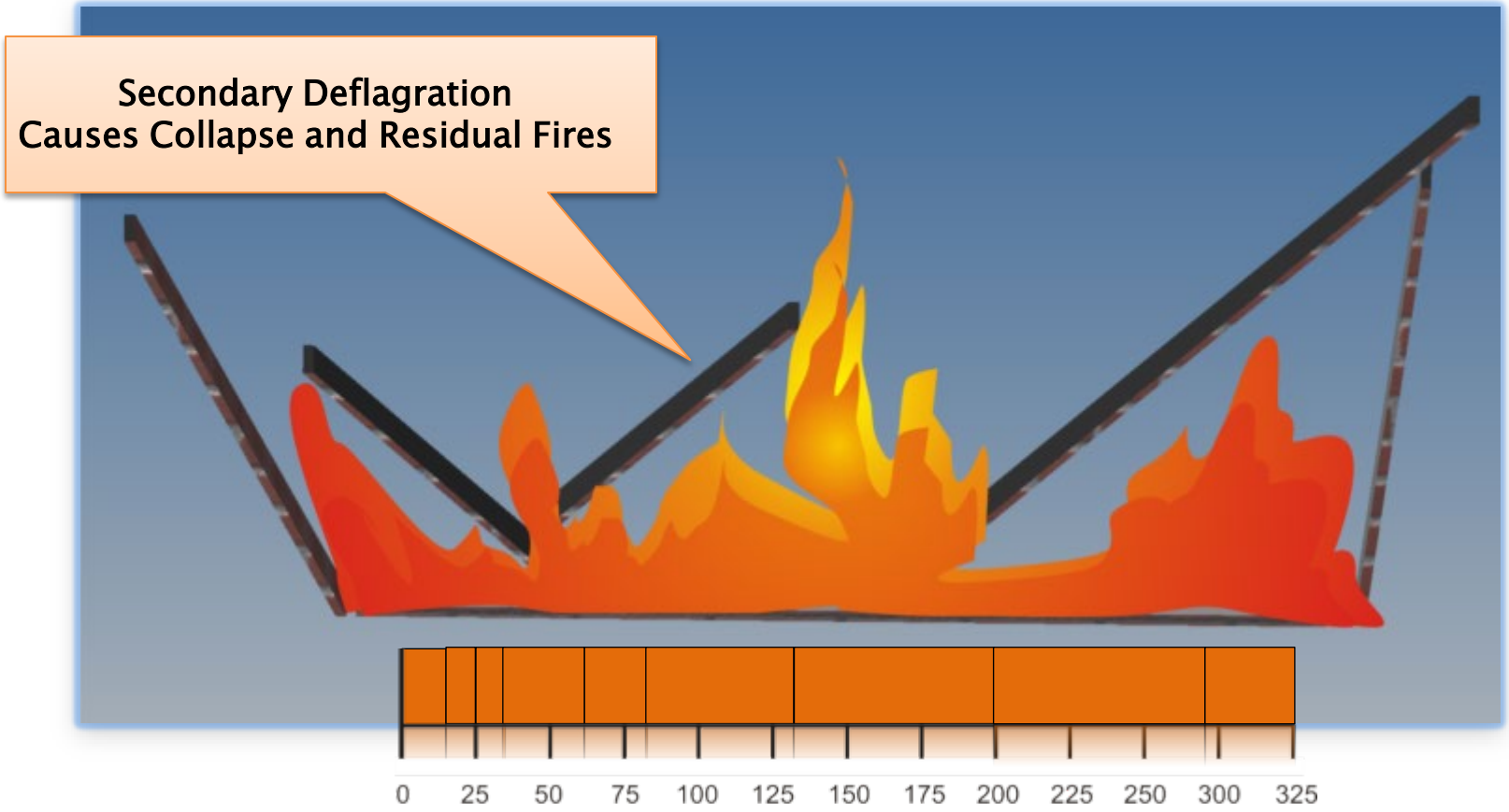
The "Typical" Explosion Event
(continued)



The "Typical" Explosion Event
(continued)



The "Typical" Explosion Event
(continued)



Fundamentals of Characterizing the Explosive Properties of Dust

Risk Factors

- Dust properties:
  - type
  - particle size
  - moisture content
- Sensitivity to oxidizer
- Ignition sensitivity and sources
- Quantity of material (fuel)
- Dispersion mechanisms
- Confinement

Source: U.S. Chemical Safety Board (U.S. CSB) Report #2003-09-I-KY

Sampling Strategy

- Consider material handling from receipt of raw materials to end product packaging
  - Dust deposits
  - Dust in cloud
- Test material with finest
- particle size
  - Baghouse or dust collector
  - Elevated horizontal surfaces
- Enclosed equipment
  - Hoppers, bins, dryers
- Locations where properties of the material could change

Source: Hughes Environmental

Testing Strategy

If In Doubt

Go/ No Go Test

"No Go"

Limited Further Concerns

"Go"

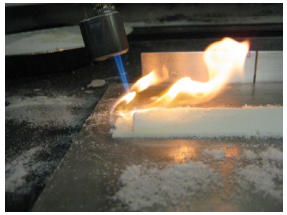
Further Testing
- MIE
- P_{max}
- K_{St}
- MEC
- MIT
- LIT
- Etc.

Mitigation & Control

Ground/Sieved/Dried

As Received

Test Protocols Defined by American Society of Testing and Materials (ASTM)



Overview of NFPA 652

Current Framework

NFPA 652

NFPA 68, 69, 70 etc.

NFPA 61

NFPA 484

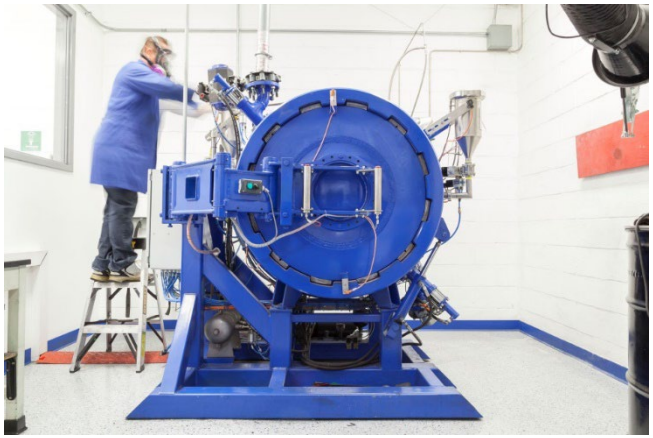
NFPA 664

NFPA 654

ASTM

NFPA 652 – What?

- NFPA 652 – Standard on the Fundamentals of Combustible Dust
  - Basic principles and requirements for identifying and managing fire and explosion hazards associated with combustible dusts
  - Directs users to the appropriate industry specific or commodity specific NFPA standard
- What are the Objectives of NFPA 652
  - Life Safety
  - Mission Continuity
  - Mitigation of Fire Spread and Explosions



NFPA 652 – Why?

- Why was NFPA 652 Created
  - There are multiple commodity specific NFPA standards
  - Requirements are sometimes inconsistent between industry sectors and dust types
  - Defines the relationship between this standard and others to address gaps or conflicts with requirements
  - Aims to simplify compliance and enforcement

Source: U.S. Chemical Safety Board (U.S. CSB) Report #2011-3-I-WV

NFPA 652 – Where?

- Where does NFPA 652 apply?
  - All industries
  - Applies to facilities and operations manufacturing, processing, blending, conveying, repackaging, generating, or handling combustible dusts

NFPA 652 – Who?

- Who has the responsibility
  - The owner/operator of a facility with potential combustible dust is responsible for:
    - Determining combustibility and explosibility hazards of the materials handled at the facility
    - Identifying and assessing any fire, flash fire, and explosion hazards
    - Managing the identified hazards
    - Communicating the hazards to affected personnel

NFPA 652 – When?

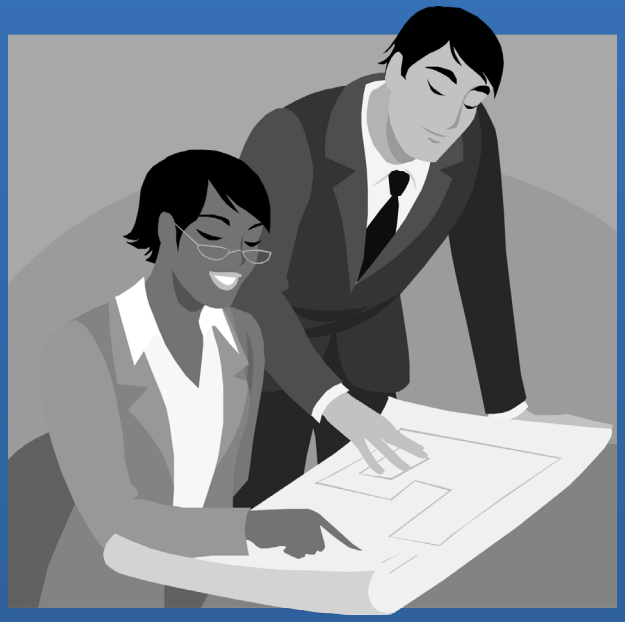
- When does this take effect?
  - Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard
  - What is retroactive?
    - Dust Hazard Analysis – Chapter 7
    - Housekeeping – Section 8.4
    - Ignition Source Control – Section 8.5
    - Management – Chapter 9

NFPA 652 – How?

- Compliance begins with an understanding of the rules
  - Requires knowledge of the standard(s)
- Understand your materials
- Evaluate your process
- Manage your Risk
  - Administrative controls
  - Engineering controls
- Maintain documentation

Source: USCSB

Introduction to Dust Hazard Analysis (DHA)



Dust Hazard Analysis (DHA)

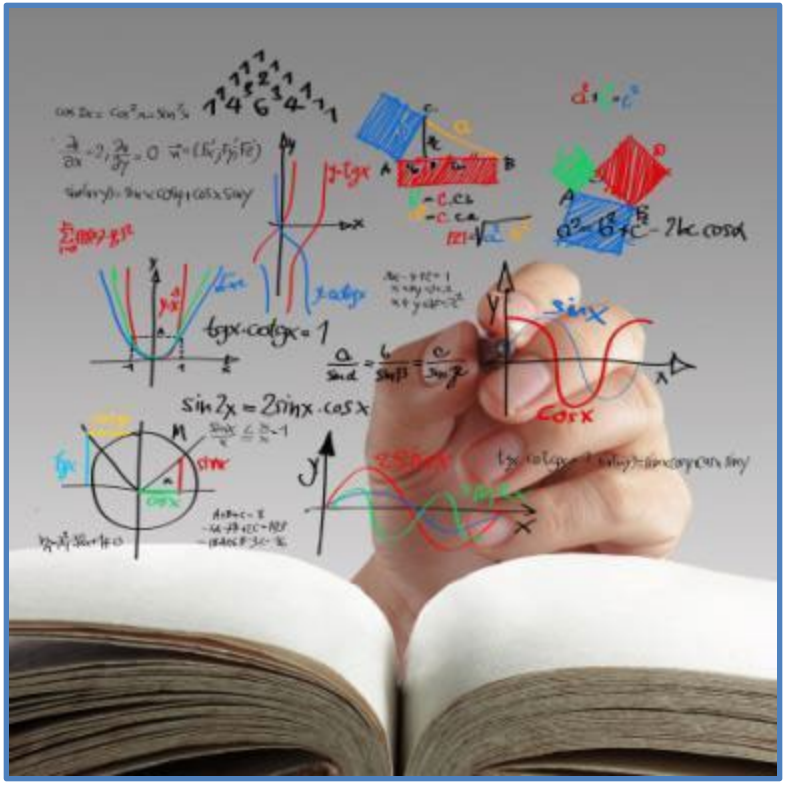
- Defined as a systematic review to identify and evaluate the potential fire, flash fire, or explosion hazards associated with the presence of one or more combustible particulate solids in a process or facility
- The purpose is to identify hazards in the process and document how those hazards are being managed

DHA Requirements

- Qualifications
  - Must be performed or led by a qualified person
- Documentation
  - Results of DHA
    - Should classify areas into three general categories
      - Not a Hazard
      - Maybe a Hazard
      - Deflagration Hazard
  - Any necessary action items
    - Process material changes
    - Physical process changes
    - Process operation changes
    - Facility changes

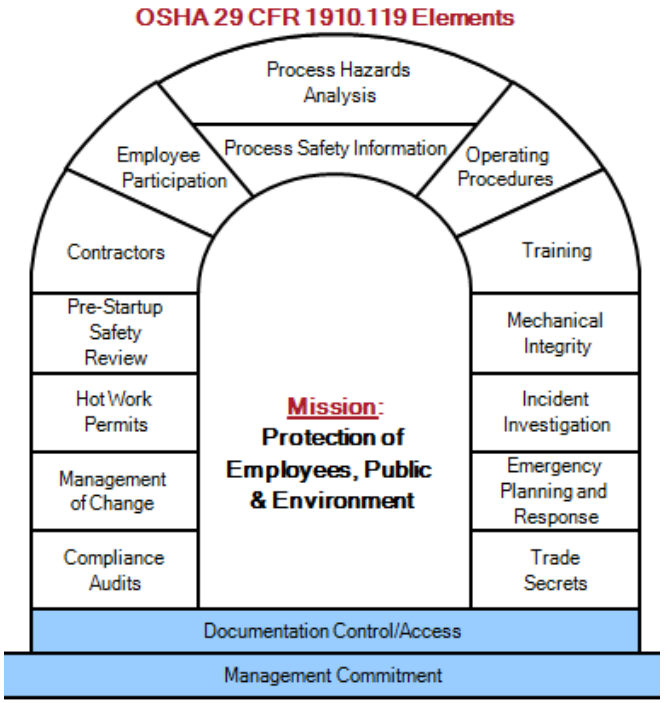
DHA Requirements
(continued)

- Methodology
  - Must identify and evaluate the process or facility areas where fire, flash fire, and explosion hazards exist
  - Must include:
    - Identification of safe operating ranges
    - Identification of safeguards in place
    - Recommendation of additional safeguards where warranted



DHA Requirements
(continued)

- Methodology (continued)
  - Acceptable methods may include, but are not limited to:
    - "What-if" analysis
    - **Checklist & "What-if" analysis**
    - Failure Modes and Effects Analysis (FMEA)
    - Fault Tree Analysis
    - HAZOP
  - OSHA PSM
    - The methodology shall be appropriate to the complexity of the process



DHA Requirements
(continued)

- Material Evaluation
  - Historical facility data or published data that are deemed to be representative of current materials and process conditions
  - Analysis of representatives samples through laboratory experiments
  - When materials are deemed to be explosible then additional testing must be performed, as required, to generate data needed to support:
    - Performance based design option
    - DHA
    - Risk assessment
    - Hazard mitigation and prevention

DHA Requirements
(continued)

- Process Systems
  - Each part of the process where combustible dust is, or could be present must be evaluated for:
    - Potential intended and unintended combustible dust transport between parts of the process system
    - Potential fugitive combustible dust emissions into a building
    - Potential deflagration propagation between parts of the process system

DHA Requirements
(continued)

- Process Systems (continued)
  - Each part of the system is considered a fire hazard if all of the following are present:
    - Sufficient quantity of combustible dust
    - Oxidizing atmosphere
    - Credible ignition source
  - Each part of the system is considered an explosion hazard if all of the following are present:
    - Sufficient quantity of combustible dust
    - Oxidizing atmosphere
    - Credible ignition source
    - Credible mechanism for suspension
    - Degree of confinement

Pre-DHA
Define the Scope & Timeframe

- Identify the boundaries of the assessment
  - What specific processes will it include
  - What buildings or facilities house these processes
  - Ensure scope meets managements expectations
  - What standards will be followed
  - What methodologies will be employed
- Determine timeframe for the assessment
  - Estimate the hours for the DHA by task
  - Identify a date for the review
    - Schedule walkthrough to ensure typical conditions are reviewed

Pre-DHA Data Collection

- Collect relevant data
  - Material properties (reactivity & ignitability)
  - Facilities and equipment layout
  - Process flow diagrams/ process & Instrumentation Diagrams
  - Material and energy flow rates
  - Utilities and locations
  - Standard Operating Procedures
  - Training Records

Pre-DHA
Material Properties

- Review Sampling Plan & associated data
- If a Sampling Plan does not exist create a material list to capture current process inputs
- Then ask:
  - Does the site have test data for these materials?
  - How complete is the data set?
  - How current is the data?
  - Is information available in literature?

Pre-DHA
Plant Layout & Process Information

- Start with a review of P&IDs or PFDs
  - If documentation is lacking, create a PFD based on the existing knowledge of the process
  - Break the process into distinct steps or nodes
  - Identify dust generating operations/equipment
    - Areas where a credible means of dispersion exists
      - Dust collectors, mixers, equipment transfer points, weigh stations, etc.
    - Check area classification for location of equipment
  - Identify areas where potential ignition sources may be introduced
  - Identify equipment equipped with explosion prevention devices

Pre-DHA
Assemble/Identify the Team

- The core team should have members with:
  - Process Expertise
  - Hazards Analysis Expertise
    - All should have a sound understanding of Dust Explosion Hazards
- Engage others as needed
  - Operations
  - Maintenance
  - Industrial Safety/Hygiene
  - Training
  - Union Representatives

Process Walk Down

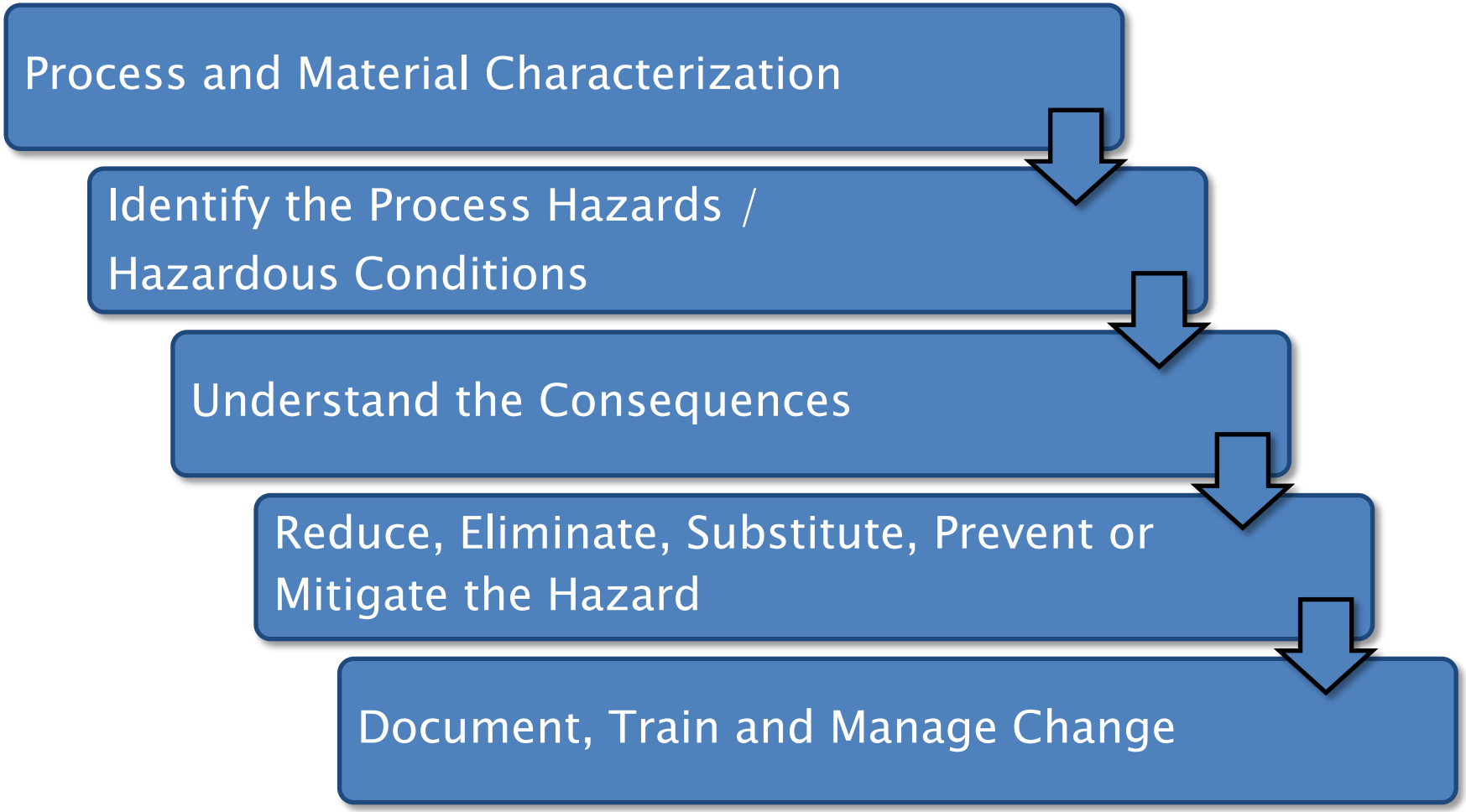
- Focus on:
  - Is a combustible dust present?
  - Is there a credible means for dispersion?
  - Does a credible ignition source exist?
  - Is an oxidizing atmosphere present?

- Some key tips:
  - Start with where materials enter the process
    - Is there a means to prevent foreign material from entering the process?
  - Interview operators in the area
    - Ask if there has been any near misses in the past
    - What type of maintenance is required for the equipment
    - Does the process go down unexpectedly
      - How often? And what usually goes wrong?

Process Walk Down
(continued)

- Key tips (Cont.)
  - Look for bonding and grounding
    - If bonding is used, check that the connection is maintained
  - Check rating of electrical equipment in classified areas
  - Evaluate dust collection equipment
    - Is it protected?
    - If so, what was the design basis?
  - Pay attention to housekeeping
    - Dust accumulation outside the process
      - Equipment housing, ductwork, horizontal surfaces, elevated structures, drop ceilings, etc.
      - Color of equipment/structure surface should be discernable
    - Ask about cleaning frequencies
    - Look for points were material is escaping the process

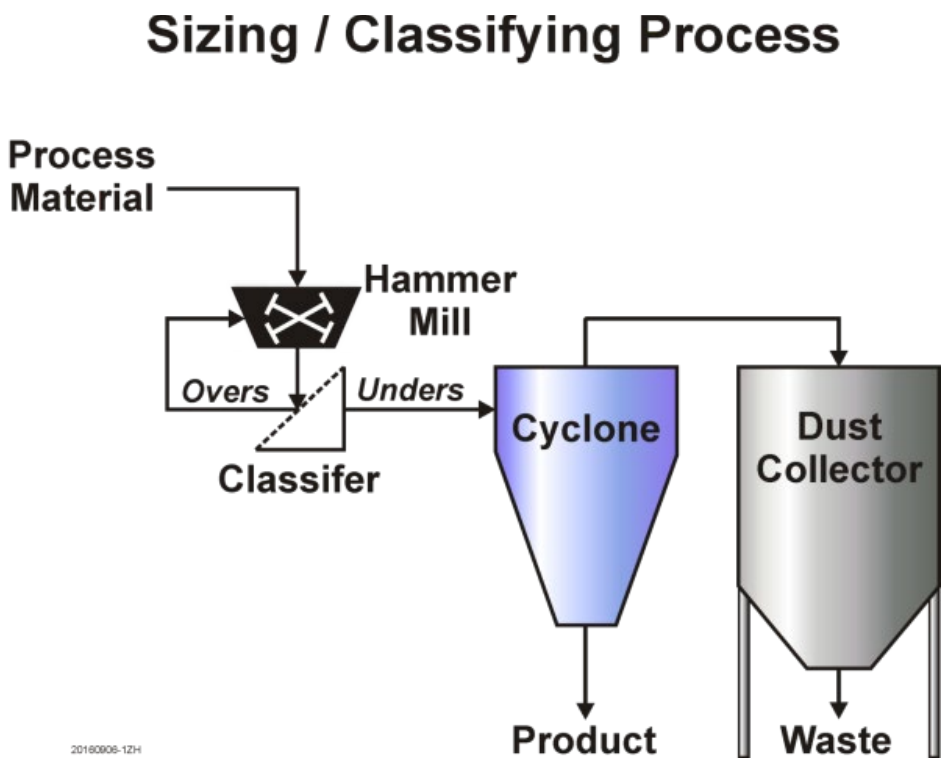
Hazard Assessment Strategy Summarized



DHA by Check List and What-if?

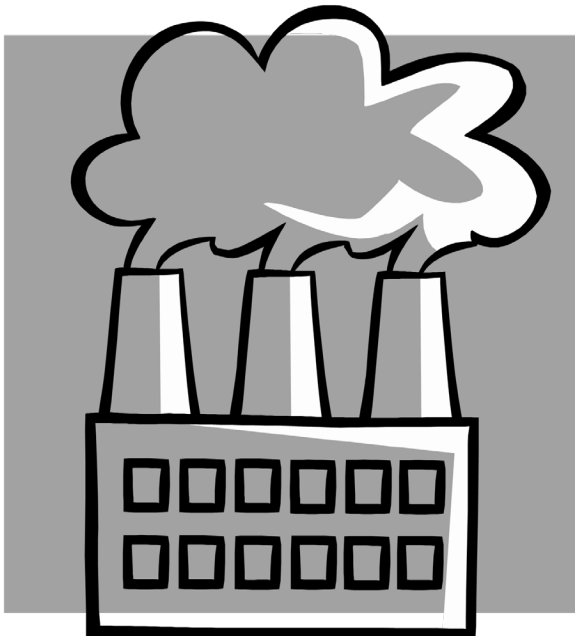
Sampling Plan Exercise

- Develop a Sampling Plan for the process below.
  - Raw material for process is shelled corn



1. What Types of Combustible Dust Does the Facility Have

- OSHA will test the dust at the lab
- Additional (less reliable) sources
  - MSDS sheets
  - Supplier data sheets and advice
  - Table 4.5.2 of NFPA 499
  - Table 1 in NMAB 353-3



2. Does the Facility Have a Housekeeping Program with Regular Cleaning Frequencies

- Is it established for floors and horizontal surfaces, such as ducts, pipes, hoods, ledges and beams to minimize dust accumulations?
- Is the dust on floors, structural members and other surfaces removed concurrently with operations?
- Is there dust accumulation of 1/32 inch thick or greater?
- What are the dimensions of
  - The room
  - The area covered with the dust

3. Are the Dust-Containing Systems Properly Designed

- Are the dust-containing systems (ducts and dust collectors) designed (so) that fugitive dusts are not allowed to accumulate in the work area?
- No fugitive dust

4. Are Dust Collectors Greater Than 8 Cubic in Volume Located Inside of Buildings

- Outside location
- Engineered containment
- Venting to outside
- Suppression

5. If Dust Explosion Hazards Exist in Rooms, Buildings or Other Enclosures

- Do such areas have explosion relief venting distributed over the exterior walls of buildings and enclosures
- Is such venting directed to a safe location away from employees

6. Are There Isolation Devices to Prevent Deflagration Propagation Between Pieces of Equipment Connected by Ductwork

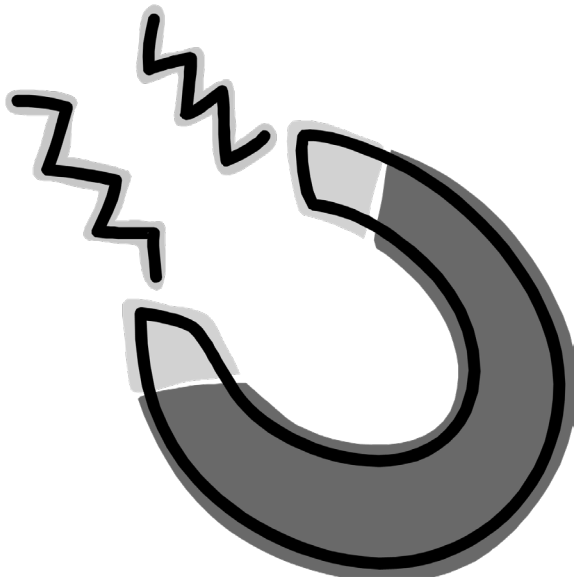
- Chokes
- Flame front diverters
- Rotary valves
- Automatic fast-acting valves
- Chemical isolation systems

7. Is There an Ignition Control Program

- Is there an ignition control program (grounding and bonding and other methods of dissipating electrostatic charge for ductwork)?
- NFPA 77 for Electrostatic Hazards

8. Are There Separator Devices to Remove Foreign Materials Capable of Igniting Combustible Dusts

- Separators
  - Magnets
    - Permanent
    - Electromagnets with power indicator
  - Pneumatic
  - Grating devices



9. Are Electrically-Powered Cleaning Devices Approved for the Hazard Classification

- Such as sweepers or vacuum cleaners used in dusty areas
- See 1910.307
- Hardware Store “Shop-vacs” are not permitted in classified locations

10. Is Smoking Permitted Only in Safe Designated Areas

- Are areas where smoking is prohibited posted with "No Smoking" signs?
- Rules followed in all locations?
- How often do you audit?
- How often do you train employees and contractors?

11. Is the Exhaust From the Dust Collectors Recycled

- NFPA 654 (2006)
  - Requires discharge to a restricted area, away from intakes
  - Recycling to the pneumatic conveying system is permitted
- Return to building air prohibited where
  - Recycle air at < 99.9% efficiency of 10 µm
  - Return of energy from a fire or explosion
  - Recycle of air where hybrid mixtures, gases or vapors are involved
  - Recycling of exhaust that reduces building air to < 19.5% oxygen

12. Does Dust Collector System Have Protection

- Does the dust collector system have spark detection and explosion/deflagration suppression systems?
- Are they sized properly?
- Do you have documentation and engineering designs?
- There are alternative measures covered later in this lecture

13. Are All Components of the Dust Collection System Constructed of Noncombustible Materials

- Big: PVC or other similar duct materials are powerful static accumulators — and combustible, as well
- Transparent view ports may
  - Disrupt electrical continuity
  - Generate static
- Temporary expedients can be a hazard

Note: Dust collector bags are typically combustible

14. Are Ducts Designed to Maintain Sufficient Velocity to Ensure the Transport of Both Coarse & Fine Articles

- Various requirements
- ~18m/s – 1068 m/min
- 3560 ft/min
- Higher velocities may be required for denser dusts/powders
- How often do you audit?
- Alarms or warnings for low velocity?

15. Are Duct Systems, Dust Collectors & Dust-Producing Machinery Bonded & Grounded

- Conductive parts can be:
  - Grounded individually
  - Bonded together and grounded
- See NFPA 77
- How often do you audit?
- Is it mentioned on your PM schedule?
- On training documents?

16. Is Metal Ductwork Used

- Worth repeating!!!
- PVC plastic or other similar duct materials are powerful static accumulators — and combustible, as well

17. In Areas Where a Hazardous Quantity of Dust Accumulates or is Present in Suspension in the Air, Does all Electrical Wiring & Equipment Comply with (1910.307) Requirements

- ES and IS calculations
- K_{St}, P_{max}, MEC, MIE and MIT data
- Compare with PPC
- Looking at Class II Division 1 and Division 2 locations
- May wish to look at European Zone 20, 21 and 22 classification
  - ATEX requirements in place for decades – rated equipment readily available

18. Does Dust Collector System Have Protection

- NFPA 654 requires a hot work permit system for all
  - Cutting and welding
  - Grinding, chipping
  - Other operations that produce sparks or open flame
  - Use of cartridge activated tools

19. Are Bulk Storage Containers Constructed of Noncombustible Materials

- Intent is to not exceed the capabilities of the fire protection system
- Metal bins are typical
- In corrosive environments and for some other process reasons
  - Bins may be fabricated from combustible high density plastic
    - Polyethylene or Polypropylene
  - Product must not be static generation (triboelectric)

20. Does the Company Use Methods to Dissipate Static Electricity, Such as by Bonding & Grounding

- For static generating dusts
- Small particle size
- What to do
  - Bonding and grounding

21. Are Employees Who are Involved in Operating, Maintaining & Supervising Facilities That Handle Combustible Dust Trained in the Hazards of the Combustible Dust

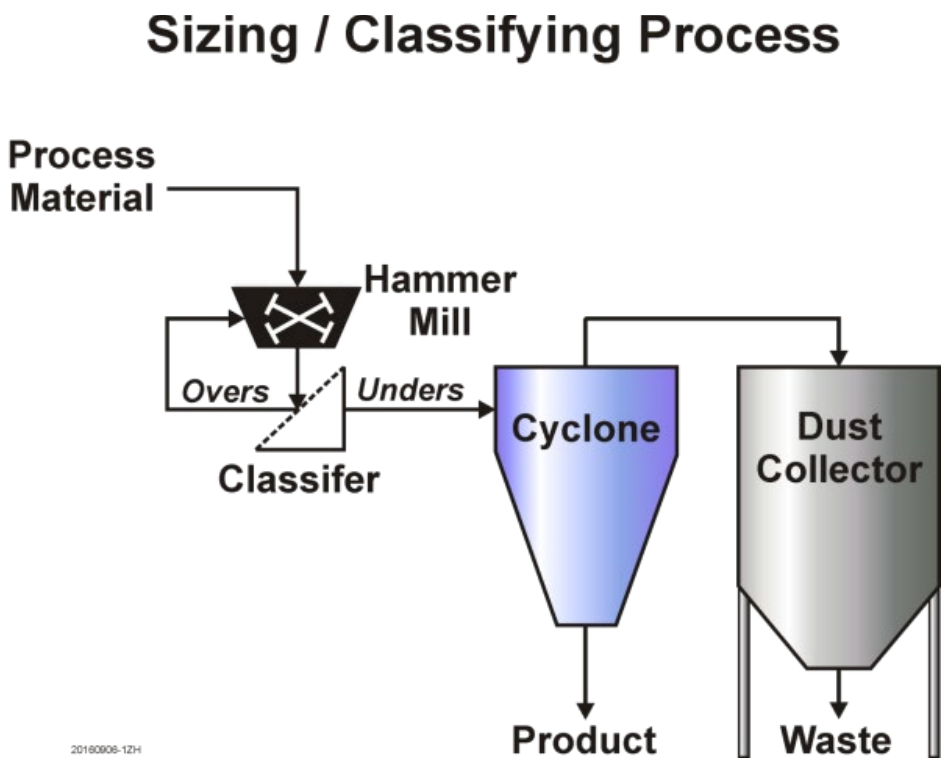
- Initial training
- Refresher
- Procedures — operations, maintenance and emergency
- Know about Management of Change (MOC) policies and issues
- Audit knowledge? How often?

22. Are MSDS' for the Chemicals Which Could Become Combustible Dust Under Normal Operations Available to Employees

- Must be available
- May not be accurate
- Employees trained in their use?
- Audit knowledge? How often?

Sampling Plan Exercise

- Develop a Sampling Plan for the process below.
  - Raw material for process is shelled corn



1.0 Overall Process:

These questions are specific to both the overall process and any sections of the process

1.1	Yes	No	NA	General Overview
1.1.1				Process changes – have there been any process changes since the last DHA was conducted? If Yes:
1.2	**Yes**	**No**	**NA**	**Life Safety**
1.2.1				Is there a possibility of a fire, flash fire, or explosion from this process? If Yes:
1.2.2				Is explosion protection and prevention in accordance with the applicable NFPA standards? If No:
1.2.3				Are employees currently wearing FR approved garments?
1.2.4				Has the process had past fires? If Yes, where and what was circumstance:
1.2.5				Does the facility have emergency response procedures?
1.3	**Yes**	**No**	**NA**	**Systems**
1.3.1				Is there an inspection, testing, and maintenance program for fire systems per NFPA?
1.3.2				Is there an inspection, testing, and maintenance program for explosion protective systems to OEM requirements?
1.3.3				Is the particulate collection system designed so fugitive particulates are not allowed to accumulate in the work area? If No:
1.3.4				Are all components of the Particulate Collection system constructed of non-combustible materials?
1.3.5				Are ducts designed to maintain sufficient velocity to ensure transport of both course and fine materials?
1.3.6				What velocity flow is the current system designed for?
1.3.7				Does the location have a hot work program that addresses ignition sources?
1.3.8				Is Combustible Particulate signage provided in the hazardous areas?

1.4	Yes	No	NA	Ignition Sources
1.4.1				Is there a credible ignition source that could ignite a particulate cloud? If Yes:
1.5	Yes	No	NA	Particulate Management
1.5.1				Does the current equipment and system generate fugitive emissions? If Yes:
1.5.2				Is there visible particulate accumulation in this area/process? If Yes, where do you observe it?
1.5.3				Is there sufficient quantity of the particle size required to propagate a flame front present? If Yes:
1.5.4				Could you have a flash fire/deflagration or explosive deflagration? If Yes:
1.6	Yes	No	NA	Housekeeping
1.6.1				Does the process have a written Housekeeping Program for the process with regular cleaning frequencies?
1.6.2				Is production equipment maintained and operated to minimize debris and particulate escape?
1.6.3				Is the Housekeeping program in compliance with Standards?
1.6.4				Is the housekeeping program setup on a routine/scheduled basis?
1.7	Yes	No	NA	Loss Prevention
1.7.1				Is process in compliance with OSHA and NFPA standards for combustible particulate?

Questions and Answers