Combustible Dust 101:

Understanding Combustible Dust Hazards

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The Combustible Dust Problem…

- Many managers and workers are not even aware of the hazards of combustible dust.
- Companies often fail to recognize the serious nature of combustible dust hazards.
- The lack of a specific OSHA standard for combustible dust means enforcement of the requirements in NFPA standards is often lax, but this is changing.
- Prior incidents are often accepted as “normal”, so the underlying causes are not identified and mitigated.
- The combustible dust hazard is often missed by inspectors who walk through the plant.

Presentation Scope

- Required elements for a combustible dust fire, flash fire, or explosion to occur.
- Identify the causes of primary and secondary explosions.
- Identify potential protection and mitigation strategies.
- Summarize the Dust Hazard Analysis (DHA) process outlined in NFPA 652.

OSHA Combustible Dust National Emphasis Program (NEP)

You are a target of the OSHA National Emphasis Program (NEP) if:

- You are covered by OSHA
- You handle/process combustible dusts and powders including (but not limited to):
  - Metal dust such as aluminum and magnesium
  - Wood dust
  - Coal and other carbon dust
  - Plastic dust and additives
  - Biosolids
  - Other organic dusts such as sugar, paper, soap and dried blood
  - Certain textile materials

OSHA Combustible Dusts NEP Inspection

- Assessment of the combustible dust threat to employees
  - Are the dusts combustible/explosible
  - Are management practices adequate?
  - Are physical controls and protection adequate for the hazard present?
  - What is the site history of fires involving dust?
  - Does the SDS indicate a dust explosion hazard?
  - Are fugitive dust accumulations hazardous?
- Collection of samples for testing and analysis
  - From high places
  - From floors and equipment surfaces
  - From within ductwork
- Review dust handling and processing equipment
- Audit of room safeguards
- Audit of ignition source management

OSHA Citations

- Citation of facilities based on the investigation outlined in the previous slide and test results using one or more of the following OSHA standards:
  - General Duty Clause Section 5(a)(1) Provide a site free of recognized explosion hazards.
  - If grain facility: 29 CFR 1910.272 grain handling standard
  - Ventilation standard 1910.94 covering abrasive blasting, grinding, polishing and buffing operations
  - Housekeeping if not a grain facility, 29 CFR 1910.22 or 1910.176 for storage areas.
  - If coal handling: 29 CFR 1910.269(v)(11)(vii).
  - Personal protective equipment standard 29 CFR 1910.132(a) if personnel could be exposed to a fireball hazard.
  - Electrical area classification violations for Class II (dust) or Class III (flock) areas 29 CFR 1910.307 or 1910.399.
  - Other standards as listed in the NEP document.

Imperial Sugar Explosion -2008

- February 7, 2008-Port Wentworth, GA
- 14 died, 36 injured
- Chemical Safety Board (CSB) investigation report and video
- http://www.csb.gov/assets/1/19/Imperial_Sugar_Report_Final_updated.pdf
- https://www.youtube.com/watch?v=Jg7mLSG-Yws&feature=youtu.be

Chemical Safety Board (CSB) Photo

http://www.csb.gov/imperial-sugar-investigative-photos/

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U.S. Chemical Safety and Hazard Investigation Board (CSB) Conclusions

- The first explosion – known as a "primary event" – likely occurred inside a sugar conveyor located beneath two large sugar storage silos.
- The conveyor had recently been enclosed with steel panels creating a confined, unventilated space where sugar dust was suspended in air at an explosible concentration.
- Sugar dust inside the enclosed conveyor was likely ignited by an overheated bearing, causing an explosion that traveled into the adjacent packing buildings, dislodging sugar dust accumulations and spilled sugar located on equipment, floors, and other horizontal surfaces.
- The result was a powerful cascade of secondary dust explosions that fatally injured 14 workers and injured 36 others, many with life-threatening burns. The refinery's packing buildings were largely destroyed by the blasts and ensuing fires.

U.S. Chemical Safety and Hazard Investigation Board (CSB) Conclusions

The explosions at the Imperial Sugar refinery in Port Wentworth, Georgia, resulted from:

- Ongoing releases of sugar from inadequately designed and maintained dust collection equipment, conveyors, and sugar handling equipment. (Design & Maintenance)
- Inadequate housekeeping practices allowed highly combustible sugar dust and granulated sugar to build up throughout the refinery's packing buildings. (Housekeeping)

Dust Standards

- NFPA Standards

Standard	Industry	Edition
NFPA 652	All	2016
NFPA 654	All- General Industry Document	2017
NFPA 664	Wood	2017
NFPA 665	Sulfur	2017
NFPA 61	Food/Agricultural	2017
NFPA 484	Metal	2015

- FM Global Datasheets
  - FM Datasheet 7-76: Prevention and Mitigation of Combustible Dust Explosion and Fire

Dust Standards

- How-to Documents

Standard	Purpose	Edition
NFPA 68	Explosion Venting	2018
NFPA 69	Suppression/Containment/Isolation/Inerting	2014
NFPA 77	Static Electricity	2014
NFPA 499	Hazardous Electrical Classifications	2017
NFPA 70	National Electrical Code	2017

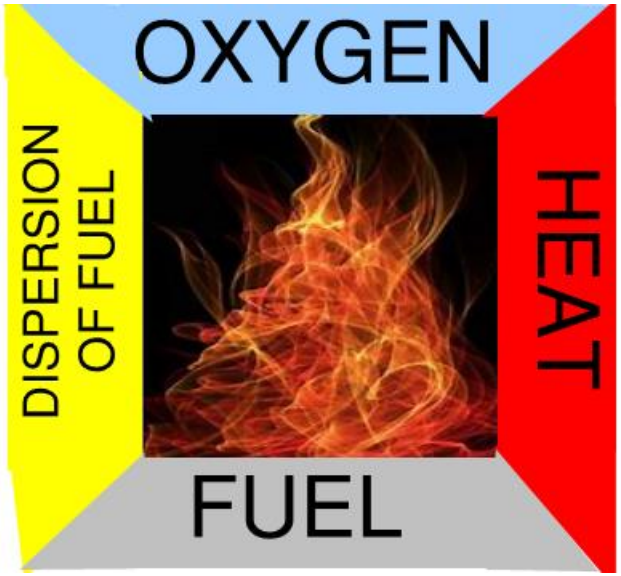
Hazards of Combustible Dust

- Fires
- Flash Fires
- Explosions

The Fire Triangle

Fire Triangle

Fire Triangle + Disersion = Flash Fire



Fuel+ Heat + Oxygen + Dispersion of fuel in air

=

FLASH FIRE

Fire Triangle + Dispersion+ Confinement = Explosion

Explosion Pentagon

Combustible Dust Explosion Pentagon: Five Elements – ALL Necessary

1. Combustible Dust
2. Oxygen in Air
3. Ignition Source
4. Dispersion
5. Confinement

Explosion Pentagon

IMPORTANT
NO DUST EXPLOSION OCCURS
if one or more elements
are missing

Element 1: Combustible Dust

Agricultural Products such as:

- Corn Starch, Dry Milk, Sugar, Powered Milk

Agricultural Dusts such as:

- Cocoa Powder, Hops (malted), Rice Flour, Wheat grain dust

Carbonaceous Dusts such as:

- Petroleum Coke, Pine Soot, Bituminous Coal, Wood Charcoal.

Chemical Dusts such as:

- Lactose, Sulfur, Calcium Acetate, Methyl-Cellulose

Plastic Dusts such as:

- Phenolic Resin, (poly)Propylene, (poly)Vinyl Chloride, Melamine Resin

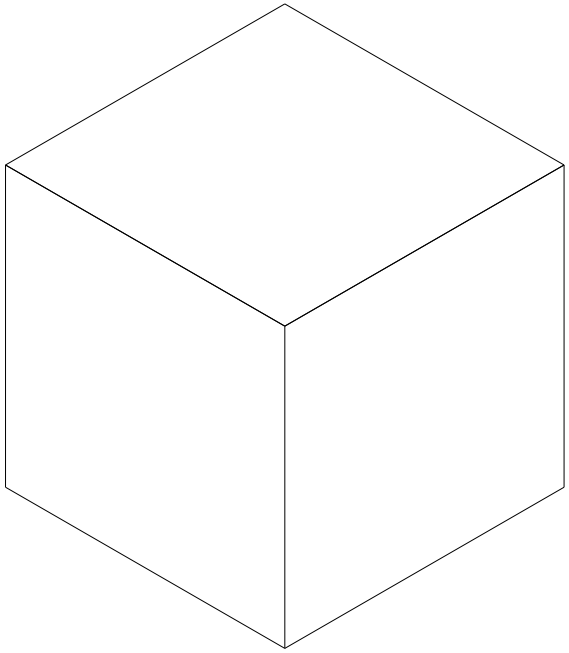
Metal Dusts such as:

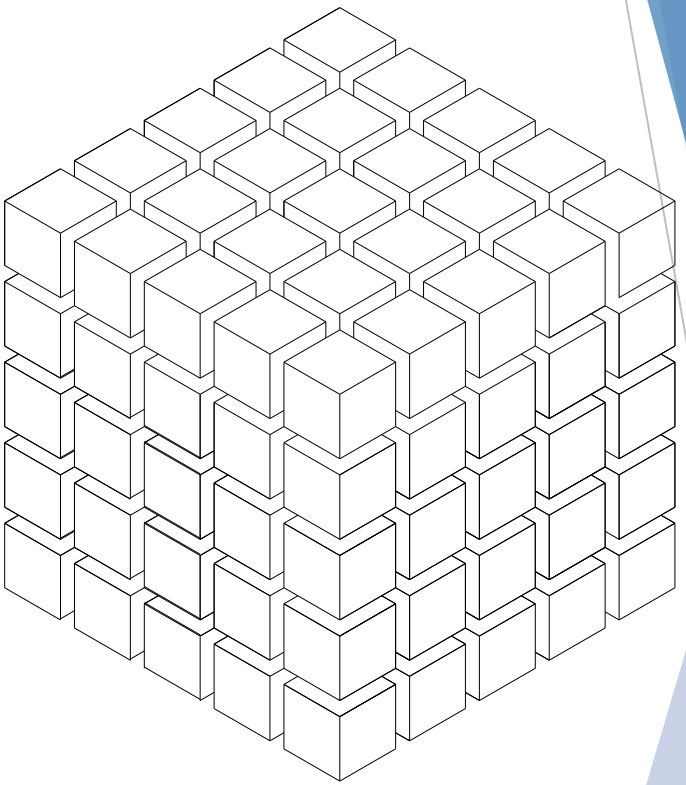
- Aluminum, Magnesium, Zinc, Bronze

Wood Dusts such as:

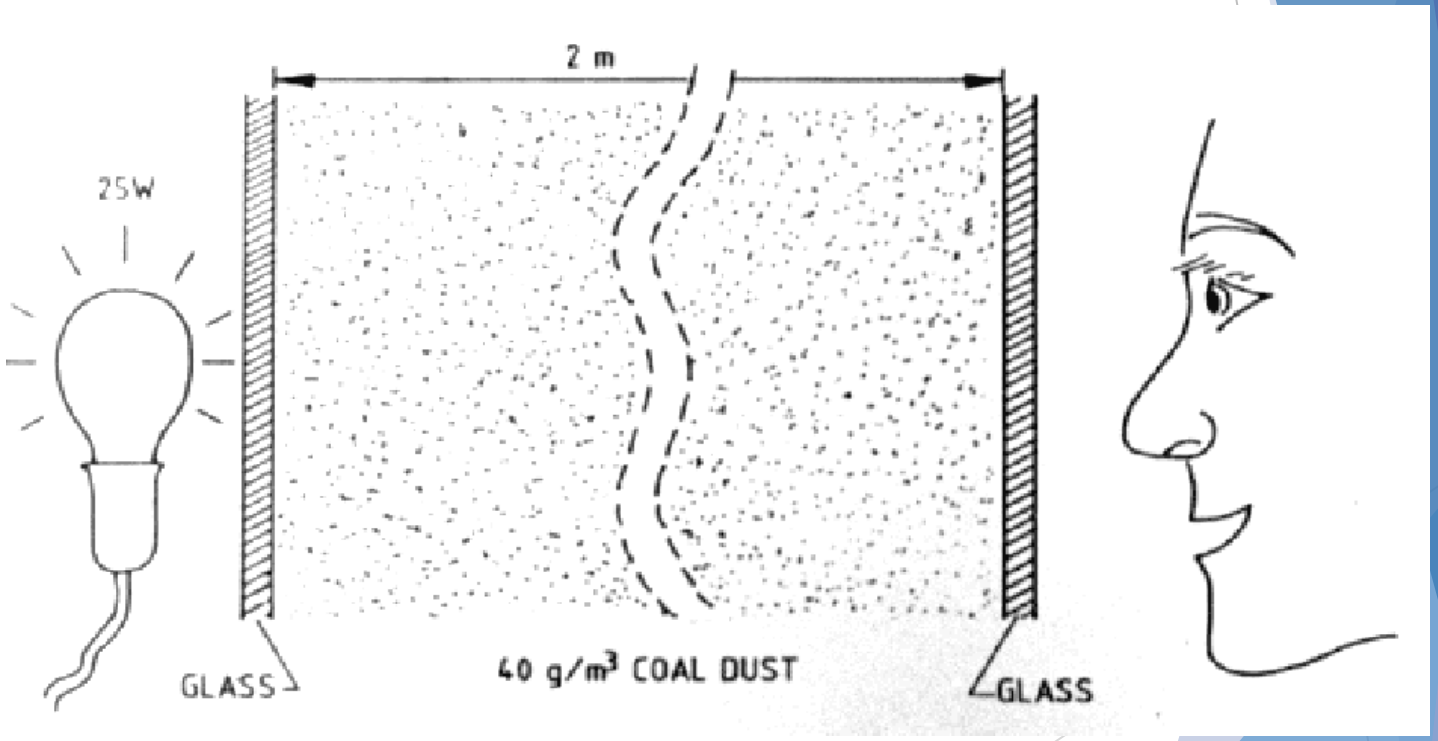
Wood Flour, Saw Dust

Elements 1, 2, and 3 are part of the Fire Triangle





Appearance of a dust cloud



A cloud of 40 g/m3 of coal dust in air is so dense that a glowing 25W light bulb can hardly be seen through a dust cloud of 2m thickness

Element 2: Oxygen in Air

- The Oxygen content in air is all that is necessary to support an explosion.
- It is everywhere
- Inerting is a possibility, but not usually the first choice.

Elements 1, 2, and 3 are part of the Fire Triangle

Element 3: Ignition Source

Ignition sources could be electrical, mechanical, or other energy source, common examples include:

- ELECTROSTATIC DISCHARGE
- SMOLDERING/BURNING MATERIAL
- SPONTANEOUS HEATING
- ELECTRIC SPARK
- FRICTIONAL HEATING/ SPARKS
- HOT WORK
- HOT SURFACES
- FLAMES
- LIGHTNING

Elements 1, 2, and 3 are part of the Fire Triangle

Element 4: Dispersion

Dispersion in the right concentration

- Dust needs to be dispersed in the air
  - MEC: Minimum Explosive Concentration

NOTE: Elements 1, 2, 3, and 4 will cause a deflagration (and without confinement, we get a flash fire)

Element 5: Confinement

Confinement can be provided by

- Buildings,
- Process equipment,
- Ducting and piping,
- Dust collection equipment.

All 5 Elements = EXPLOSION

Explosion Pentagon

EXPLOSION

IMPORTANT
NO DUST EXPLOSION OCCURS
if one or more elements
are missing

Prevention Methods- Remove an ingredient from the recipe

To prevent a fire, flash fire, or explosion, we have to remove one of the needed elements.

- If we have a fuel, ignition source, oxygen, fuel dispersion in air, and confinement, we can have an explosion. If we remove one of those elements, we cannot have an explosion.
- If we have a fuel, ignition source, oxygen, and dispersion in air, but no confinement, we can have a flash fire, but if we remove one of the elements, we cannot have a flash fire.
- If we have fuel, ignitions source, and oxygen, we can have a fire, but if we remove on of the elements, we cannot have a fire.

Explosions

- Primary Explosion
- Secondary Explosion

Primary Explosions

- Combustible dust cloud within processing equipment (e.g. silo, hopper, mill, dryer etc.)
- Ignition of dust cloud causes flame to propagate through the cloud – creating heat
- Heat causes combustion products to expand
- Expansion within confined volume creates pressure
- Maximum possible pressure will depend on the concentration of dust and the dust combustion properties – normally more than 6 bar
- Equipment unlikely to survive the maximum pressure, so equipment bursts and releases the pressure suddenly = explosion

Secondary Explosions

Three possible ways a secondary explosion occurs:

- Pressure released from a primary explosion in a vessel rouses dust in the workplace, creating a secondary dust cloud in the workplace
  - – flame vented from the vessel ignites the secondary cloud.
- Primary explosion initially vents unburned dust, creating a dust cloud in the workplace
  - – flame vented from the vessel ignites this.
- Pressure vents from a primary explosion in one vessel into a second vessel, rousing dust
  - - flame from the primary explosion ignites this.

Secondary Explosion

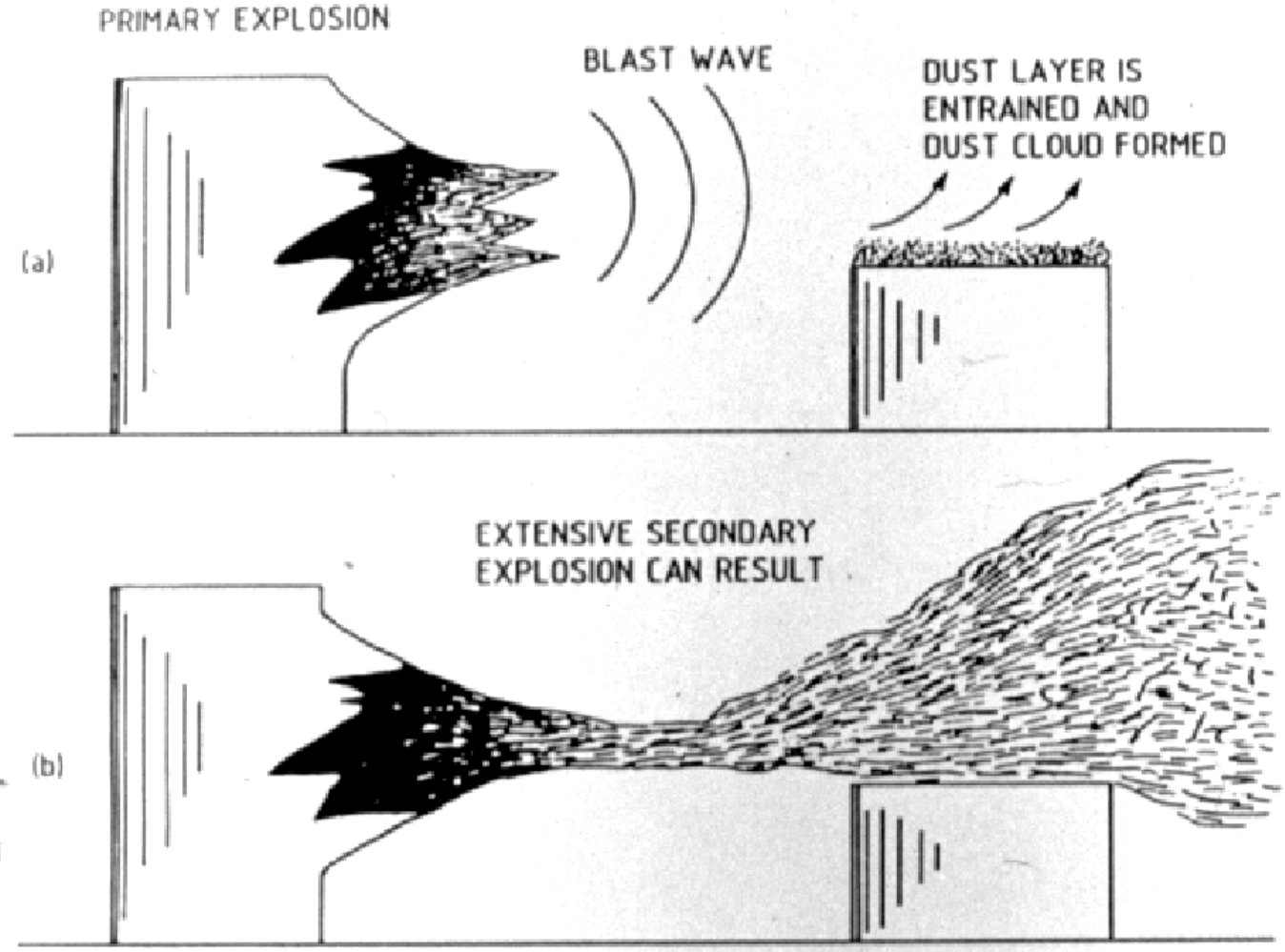
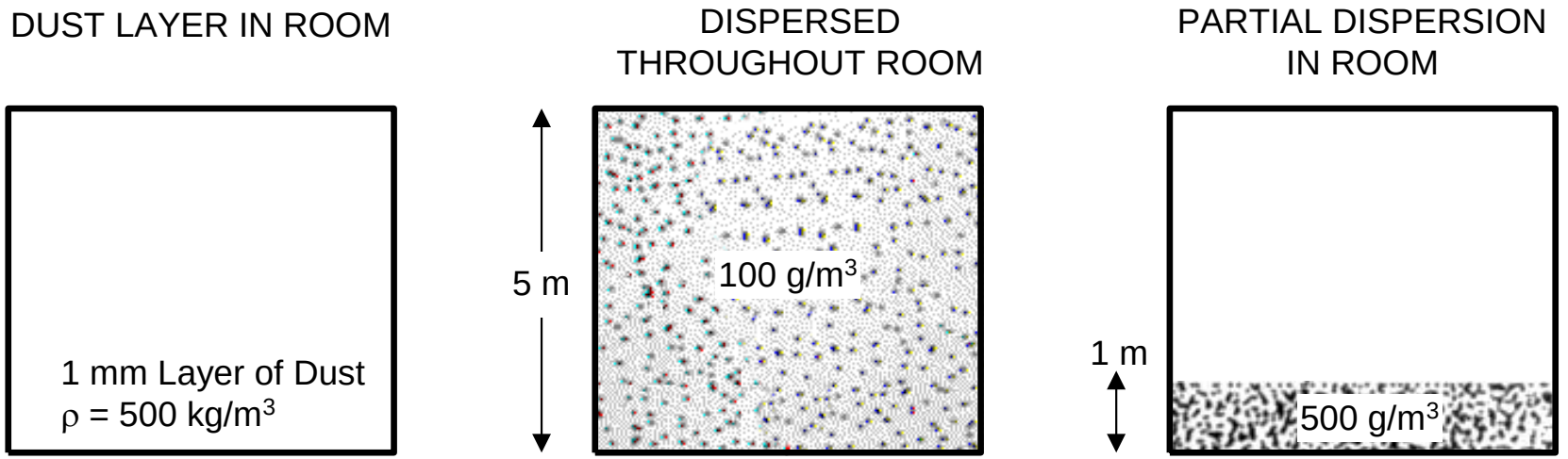


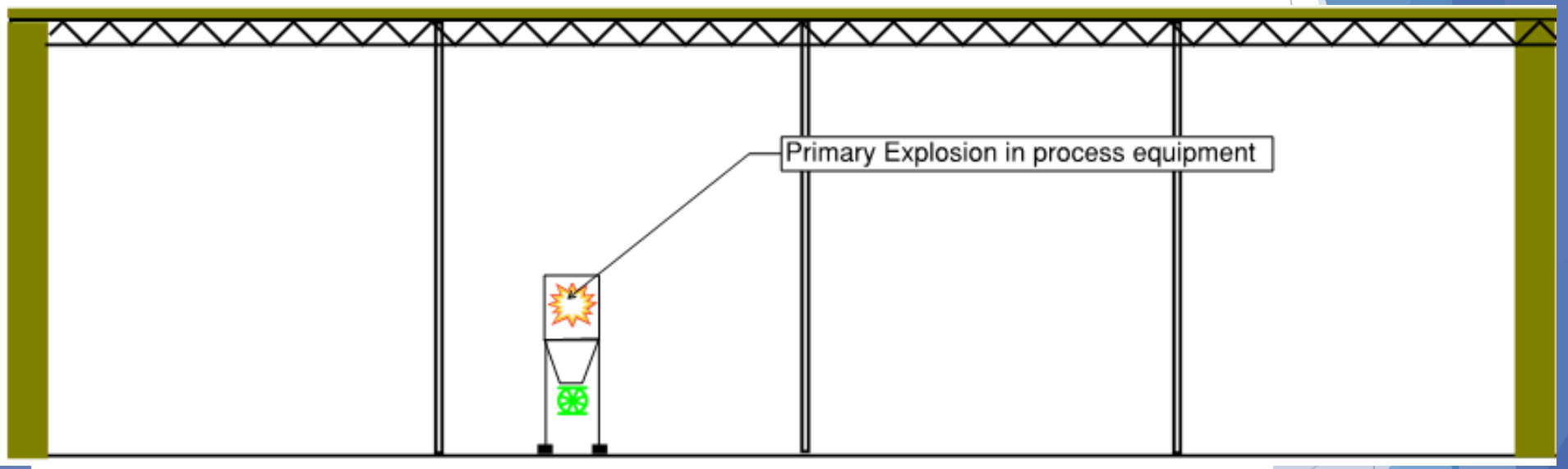
Figure 1.7 *Illustration of how the blast wave from a primary explosion entrains and disperses a dust layer, which is subsequently ignited by the primary dust flame*

The hazard from dust layers

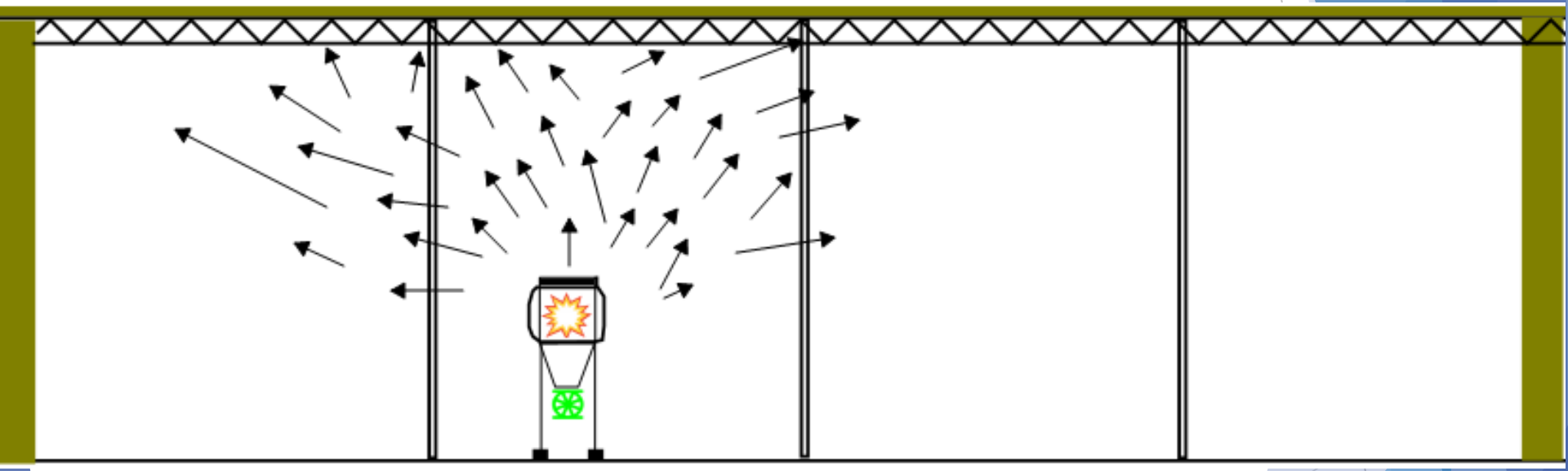


Dust Explosion Sequence

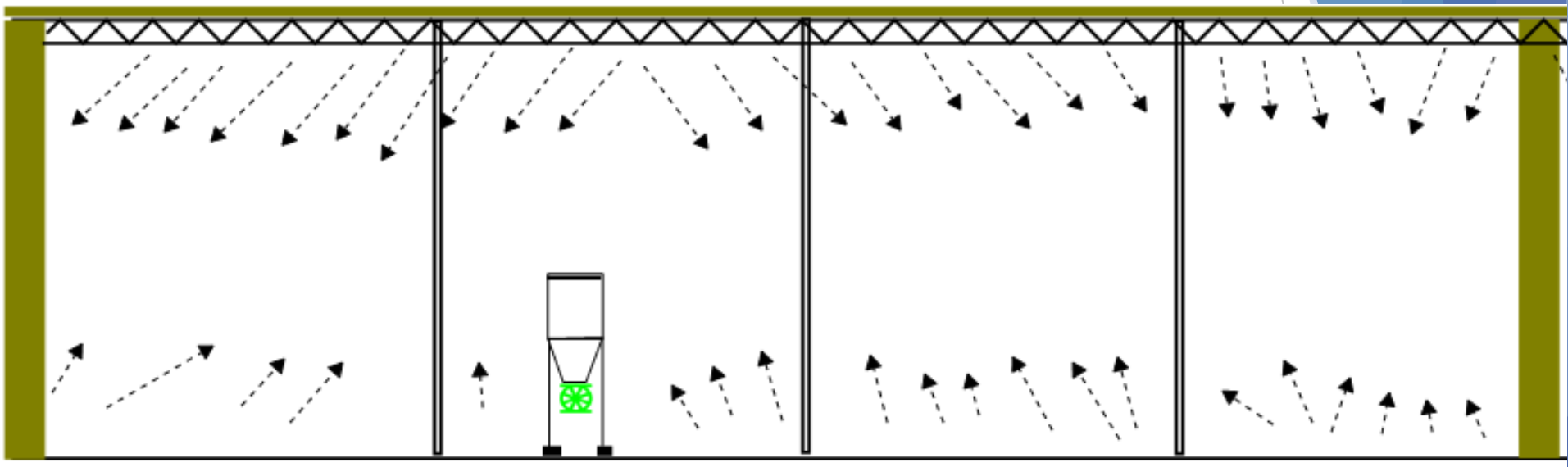
Step 1- A primary explosion occurs in process equipment



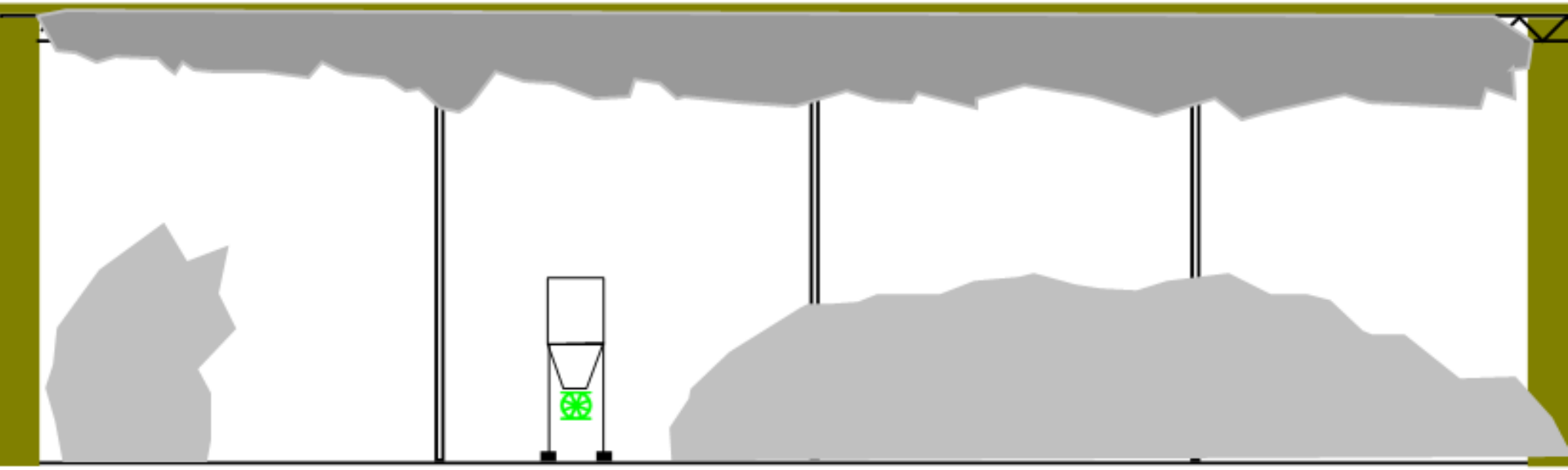
Step 2 - Shock waves are created by the primary explosion



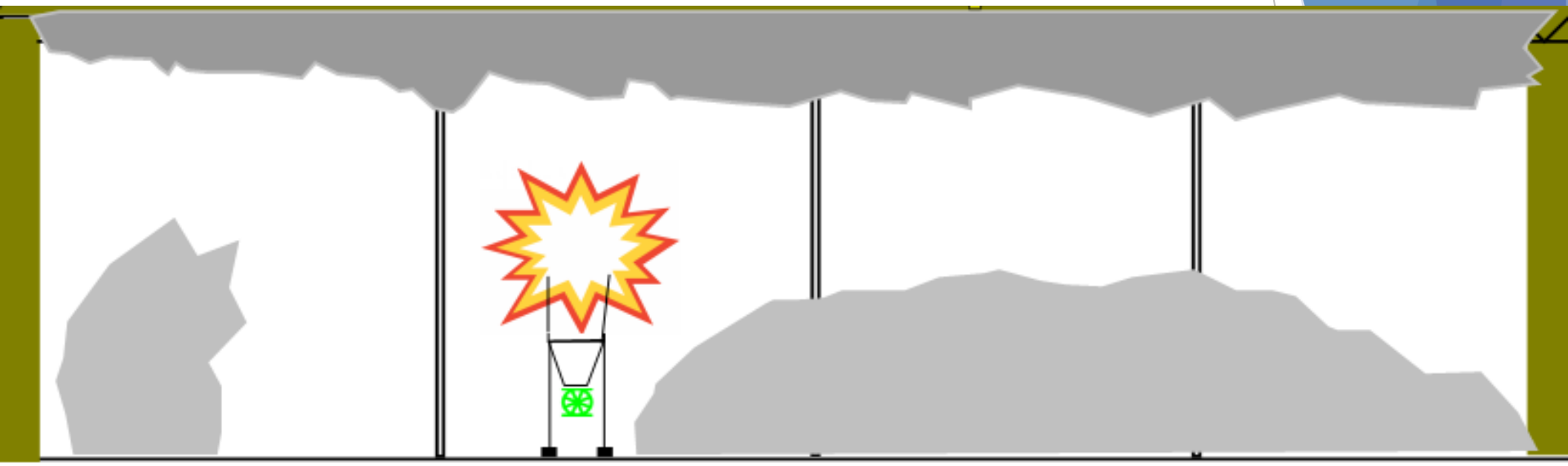
Step 3 - The shock waves are reflected off surfaces and accumulated dust becomes suspended in air



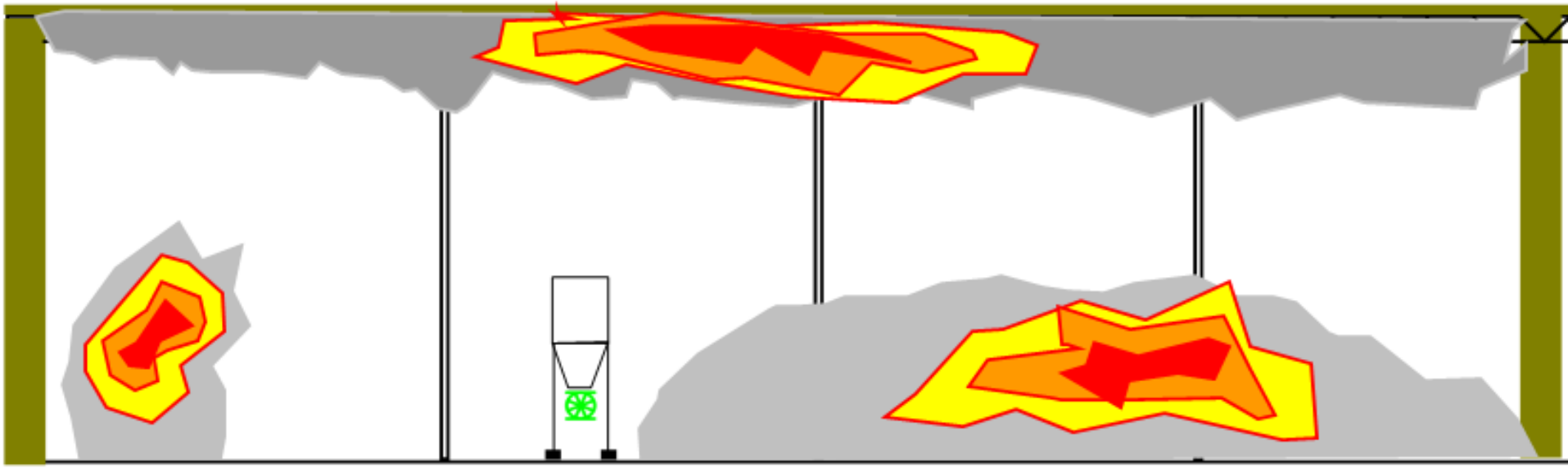
Step 4 - Dust clouds form in the air as the accumulated fugitive dust becomes suspended in air from the shock waves



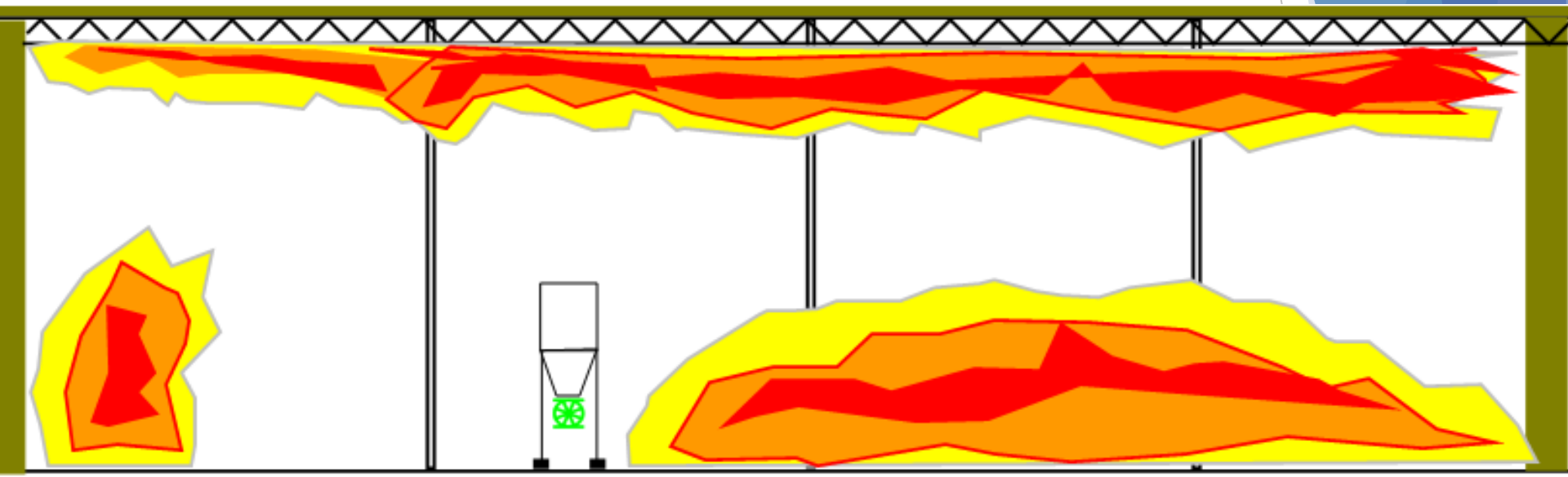
Step 5- Pressure in the vessel increases until the equipment ruptures and the primary explosion releases flame into the workspace



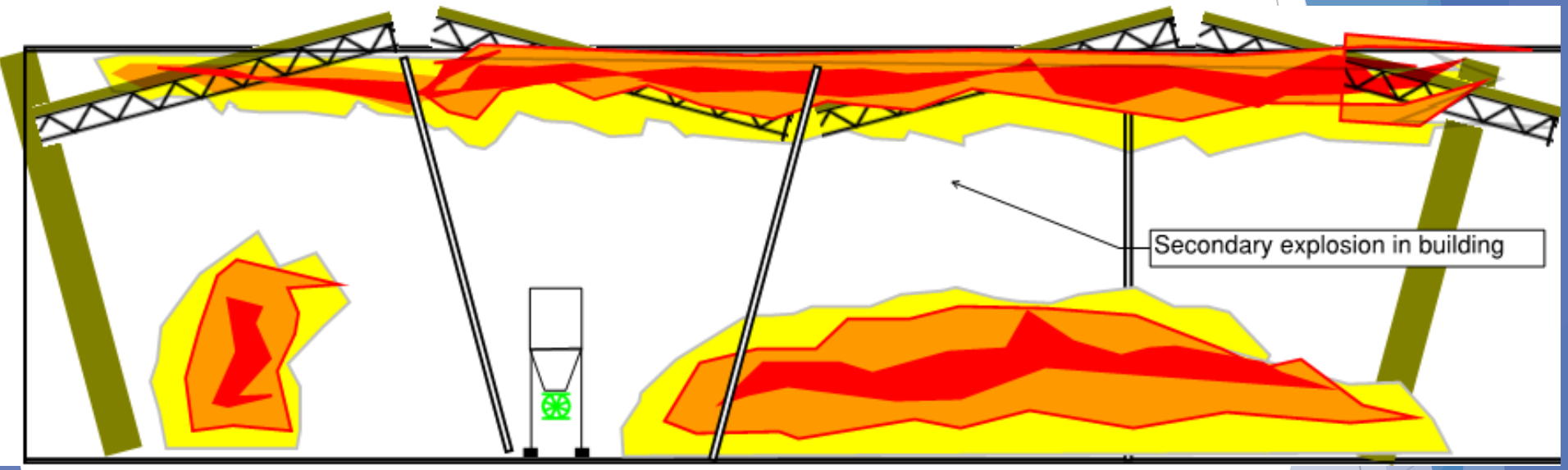
Step 6 - A deflagration occurs when the suspended clouds of dust are ignited by the flame from the primary explosion



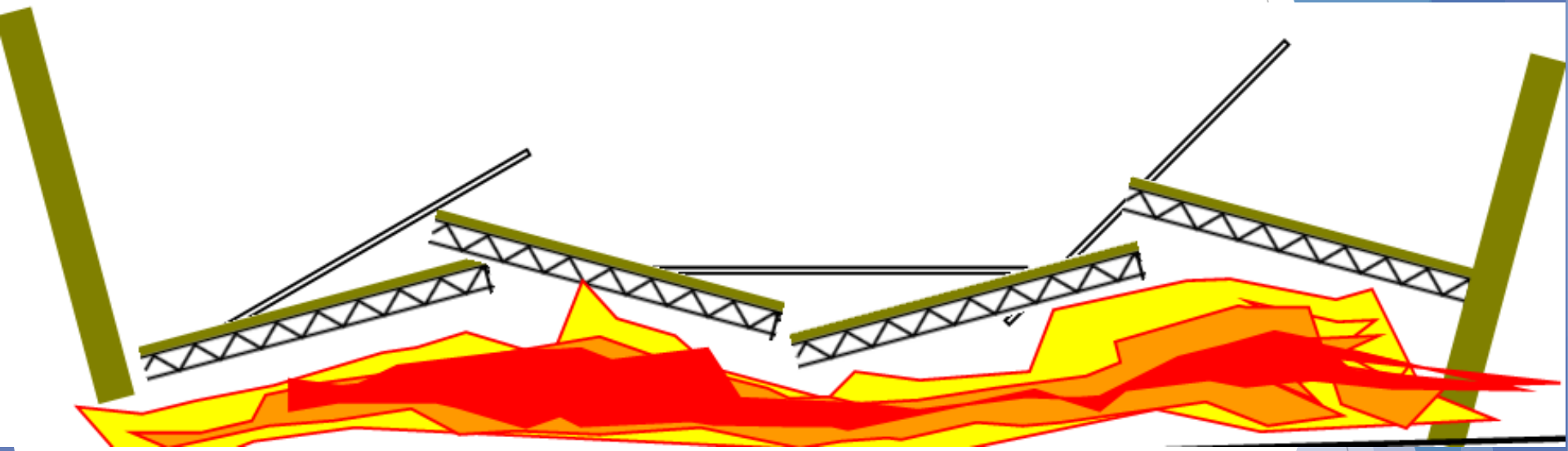
Step 7- Deflagration is propagated through the suspended dust clouds



Step 8 - Pressure increases in the building until the pressure is vented from the building (secondary explosion),



Step 9- Walls and roof collapse and interior fires continue to burn within the collapsed building



Avoiding Secondary Explosions

- Secondary Explosions are usually **more destructive** than the primary explosion

- Causes
  - poor housekeeping
  - interconnecting equipment
  - inadequate explosion relief design

- **Housekeeping** is the #1 way you can reduce your combustible dust exposure, by limiting the amount of fugitive dust that is available to propagate a secondary explosion.

Managing the fugitive dust problem

- Three ways of managing:
  1. **Contain the emission**—repair/ maintenance to tighten up equipment
  2. **Capture the emission**—effective dust collection measures
  3. **Clean the emission**

- The goal is to stop and/or capture the emission so that cleaning is a periodic (and not constant) and manageable task!
- Becomes more important as the plant begins to age.


AVOID A FALL!
USE HANDRAILS

Use an approved portable or central vacuum

NFPA 652- Standard on the Fundamentals of Combustible Dust

The owner/operator of a facility with material that could be a combustible dust must:

- Determine the combustibility and explosibility of the material (Chapter 5)
- Identify and assess any fire, flash fire, or explosion risks (Chapter 7)
- Manage the fire, flash fire, and explosion risks (4.2.4)
- Communicate the hazards to affected personnel (Section 9.5)

What is a Dust Hazard Analysis (DHA)

- First it is **NOT** a Process Hazard Analysis (PHA)
- A PHA is a very detailed review, which involved a node by node analysis of a process or processes. The goal of a PHA is to create a Risk-Ranked Table of concerns and then specific follow-up actions that will be managed until resolve.

- **Dust Hazard Analysis (DHA),** includes a thorough review of P&IDs, PFDs, meeting with operators, engineering, and maintenance staff to identify materials, processes and procedures, management control programs, emergency response programs, and existing protection and prevention measures in place.
- Will determine the necessary prevention, protection, ignition source controls, and consequence controls to establish the Basis of Safety for the equipment.
- DHA results in a report that outlines the Basis of Safety for the powder handling equipment, and recommendations to address deficiencies.

Our Typical Approach

- Initially a visit to perform a walk-through assessment (1 day)

  Identifies gaps in information, and protection that will need further evaluation as part of the DHA.

- Request documentation including PFDs, P&IDs, Equipment Approval Drawings for powder handling equipment. Create a sampling plan and obtain samples for testing. Send sample for testing based on the anticipated Basis of Safety.

- Dust Hazards Analysis (2-3 Days)

  Includes a thorough review of P&IDs, PFDs, meeting with operators, engineering, and maintenance staff to identify material, processes and procedures, management control programs, emergency response programs, existing protection and prevention measures in place, etc.

Qualifications

- DHA must be completed by a qualified person.
- Qualified Person: A person who, by possession of a recognized degree, certificate, professional standing, or skill, and who, by knowledge, training, and experience, has demonstrated the ability to deal with problems related to the subject matter, the work, or the project.

Step one:
Determine Material Properties

To determine **combustibility**:

- Test Method for Readily Combustible Solids- screening test

To determine **explosibility**:

- Can assume the material is explosible
- Can test with the go/no go screening test ASTM E1226

Sampling Plan- Per NFPA 652

The sampling plan shall include the following:

- Identification of locations where fine particulates and dust are present
- Identification of representative samples
- Collection of representative samples
- Preservation of sample integrity
- Communication with the test laboratory regarding sample handling
- Documentation of samples taken
- Safe sample collection practices

Dust Hazards Analysis (DHA) is required if combustible or explosible

- Combustible – it will burn
- Explosible
  - Dusts which ignite and propagate away from the source of ignition are considered “explosible”.
  - Dusts which do not propagate flame away from the ignition source are considered “non-explosible”.

Dust Hazards Analysis

- Systematic approach required
- Look at specifics of the operation of individual items of equipment, and the interaction of equipment
- Consider specific material properties
- Identify how, where and why explosible dust clouds could arise – normal and abnormal operation
- Classify Hazardous Areas
- Identify potential ignition sources and whether these can be totally eliminated
- Assess whether consequences of explosion will be serious (risk to personnel and plant)
- Define a Basis of Safety – Prevention or Protection

Definition of Control Measures

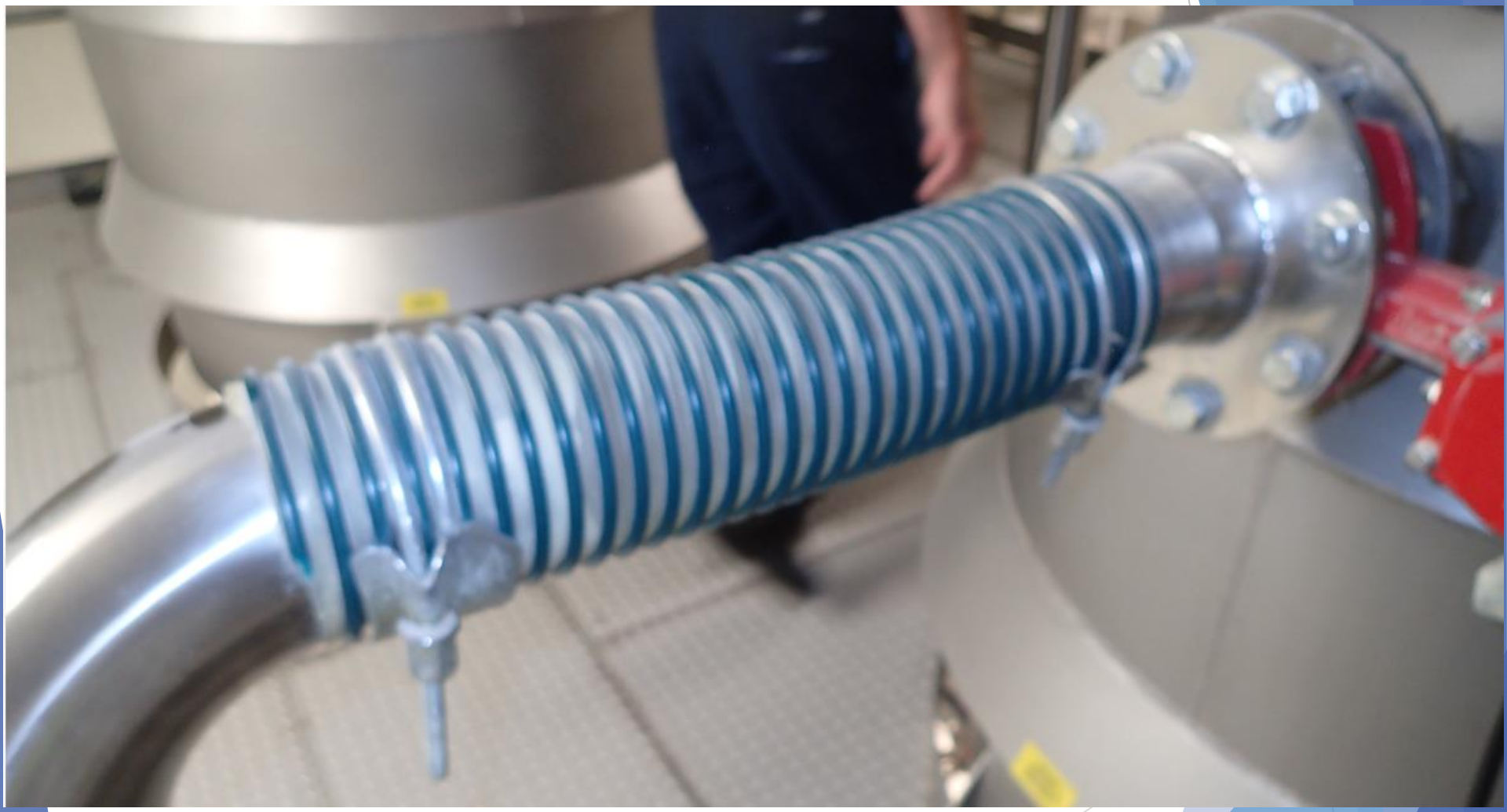
- Preventive Measures
  - Avoid generating combustible dust clouds
  - Eliminate air (inerting)
  - Eliminate Ignition Sources
- Protective Measures
  - Explosion Relief
  - Explosion Suppression
  - Explosion Containment
  - Explosion Isolation
- Management Controls
  - ITM, Change Management, Housekeeping, Training

Potential Ignition Sources

- Friction
- Impact
- Static
- Flame / Hot work
- Hot Surfaces
- Electrical Equipment
- Self Heating

Control of Static

- Bonding Straps
- Earthing (grounding)
- Antistatic Hoses
- Antistatic Filter Bags



Basis of Safety

- Describes Equipment
- Material Transfer Rate
- Air Flow Rate
- Powder Data
- Ignition Sources
- Potential for Explosive Atmosphere
- Primary Basis of Safety
- Ignition Controls
- Consequence Controls
- Management Controls

Recommendations

- ***Priority 1:*** Recommendations that relate to either a high-risk exposure to the business or serious life safety issue. These require attention as a matter of urgency and will need to be rectified within an agreed time scale.

- ***Priority 2:*** Recommendations that relate to a moderate-risk exposure to life safety or physical assets. These will need to be implemented within a reasonable time scale determined by practicalities, availability of the resources, economic constraints, as well as the possibility of other influences. The time scale for implementation will be agreed with the site.

- ***Priority 3:*** Recommendations that represent opportunities for further risk reduction, which the site should consider and address as appropriate. Unless noted otherwise, there is no time scale for implementation.

Management Controls

Basis of Safety Notebook

Prepare a Combustible Dust Basis of Safety notebook (and equivalent electronic format) that maintains current documentation of Processes (PFDs or P&IDs) and equipment for which a BOS is deemed necessary.

Classified Electrical Equipment Plan:

Prepare a plan indicating the areas of the plant that are classified as Class II Division 1 or 2 areas

- Inspect and modify all electrical equipment within these areas to ensure the equipment is suitable for use within those areas.
- DON'T OVER-CLASSIFY!

Process & Technology Information

- Process performance parameters
- Properties of the materials being handled
- Documents such as design drawings (PFDs, P&IDs, certified or approved equipment drawings)
- Design codes and standards used as the basis for both the process and the equipment
- Equipment manufacturers' operating and maintenance manuals
- Standard operating procedures
- Safety systems operating parameters

Vent Closure Details

- Document and maintain vent closure details and design parameters for each explosion vented vessel.
- Complete a form similar to NFPA 68 Figure A.11.2 and attach relevant supporting design information, as applicable.
- If design information is not available, engage the services of a qualified consultant to assist.

Management of Change

Implement a written Management of Change program to evaluate proposed changes to facility and processes, both physical and human, for the impact on safety, loss prevention, and control.

Emergency Response Plan

Emergency Response Plan: Review existing Emergency Response Plan to include potential combustible dust related emergencies (fire, flash fire, or explosion) and appropriate emergency response procedures.

Preventive Maintenance Program

Implement a complete inspection, testing, and maintenance program for all explosion prevention and protection measures relied upon for safety.

Written Operating Procedures

Review and improve, if necessary, written procedures for operating the facility and equipment to prevent or mitigate fires, deflagrations, and explosions from combustible particulate solids.

Training on Combustible Dust

Implement a formal training program, to include initial and refresher training, relative to the combustible dust hazards in the workplace. Maintain training records for all training completed.

- All employees
- All contractors
- Temporary employees
- Visitors

OPPORTUNITIES

Key ways YOU can help for Day-to-Day

- Identify any combustible dust risks present in your facility
- Engage a qualified person to conduct a Dust Hazard Analysis
- Increase awareness of combustible dust hazards
- Create a culture that does not tolerate complacency with regard to combustible dust
- Be another set of eyes when walking the plant and proactively report dust accumulations and equipment in need of repair. (Take a photo and submit a work order)
- Be proactive about identifying and enforcing hazardous electrical classification areas within the plant
- Engage Change Management reviews where the change involves combustible dust, or will be located near powder handling areas

Fugitive Dust Emissions

- **Housekeeping** is the #1 way you can reduce your combustible dust exposure, by limiting the amount of fugitive dust that is available to propagate a secondary explosion
- Consider providing a visual cue for employees by placing some colorful circles on horizontal surface (floor and other horizontal surfaces up high)
- When the underlying color of these circles becomes obscured by the fugitive dust layer, it's a visual cue that its time to clean
- When color of underlying surface is obscured- Class II Div 2
- When accumulations reach 1/8 inch, then Class II Div 1

Takeaways…

- Increased awareness of the hazards of combustible dusts.
- Reviewed the Three C's: CONTAIN, CAPTURE, and CLEAN
- Explained the required elements for a combustible dust fire, flash fire, or explosion to occur.
- Identify the causes of primary and secondary explosions, and identify potential protection/mitigation strategies.
- Summarize the Dust Hazard Analysis (DHA) process outlined in NFPA 652, for performing a risk assessment of processes and equipment that handle or generate combustible dust within a facility.

Questions?