Combustible Dust: Food That Goes Boom

By Merrill Childs
Cargill – Eddyville, Iowa

Iowa-Illinois Safety Council
Coralville, IA
April 12, 2018

Cargill

- Food and Agriculture Products
- Based in Minneapolis
- Starches, Sweeteners & Texturizers NA
  - Corn Starch
  - Animal Feed
  - Sweeteners
  - Fermentation products
- Other Businesses

Contact Information

Feel free to contact me with any questions

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Disclaimer

The information in this presentation are my opinions only. Verify for yourself any information before you use it. I am not liable for any use of this content.

Product brand names are examples only

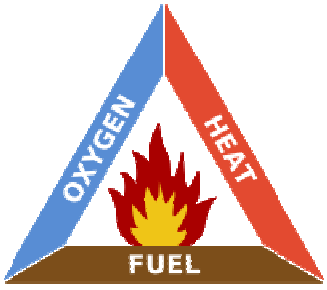
Combustible Dust

- Merrill's Objectives
  - Protect people from dust explosions
  - Protect property from dust explosions
  - Regulatory Compliance
  - Appropriate level of control

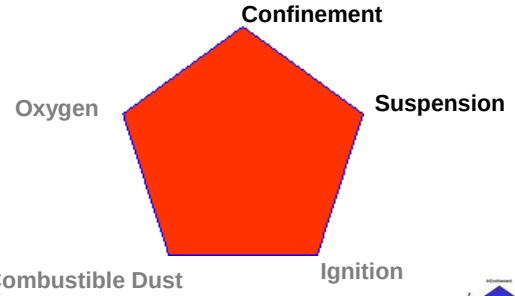
Agenda

- Why common dust explodes
- History of dust explosions
- OSHA ??????????
- NFPA Combustible Dust standards
- Combustible dust properties (Kst, Pmax, MIE)
- Dust Explosion Prevention
- Explosion venting
- Explosion suppression
- Explosion isolation
- Housekeeping and flash fires
- Demonstration of small dust explosion

Fire Triangle



Dust Explosion Pentagon

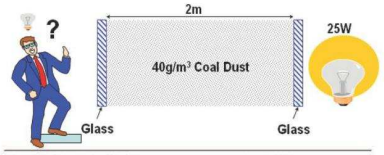


How Can Food Dust Explode?

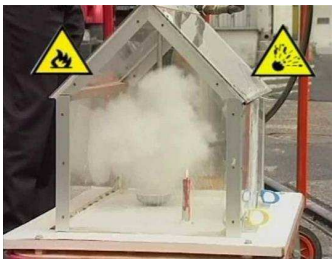
How much dust is needed?

Appearance of an Explosible Dust Cloud

A cloud of 40g/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 (Eckhoff)



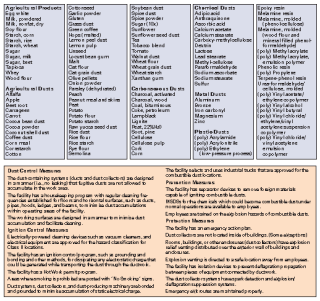
Demonstration of Dust Explosion



Combustible Dust

Does your company or firm process any of these products or materials in powdered form?

If your company or firm processes any of these products or materials, there is potential for a "Combustible Dust" explosion.



OSHA Occupational Safety and Health Administration U.S. Department of Labor

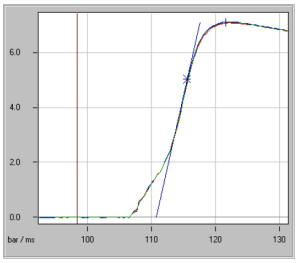
Includes:

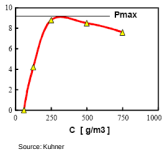
- Corn Starch
- Cocoa Powder
- Sugar (10x)
- Rice Flour
- Powdered Milk
- Carrot Dust
- Tea

20 Liter Sphere

1 m³ Vessel

P_{max} and K_{st}





Source: Kuhner

For a 20-l Test Apparatus the following equation applies:

$$0.02\ [m^3]^{1/3} \times (dP/dt)max\ [bar/s] = Kmax\ [m \cdot bar/s]$$

Are All Dusts the Same?

- K_{St} – Deflagration Index (Speed of reaction)
  - St 0 0 Non-explosible
  - St 1 0-200 Weak to Moderate
  - St 2 200-300 Strong
  - St 3 >300 Very Strong
- P_{max} – Maximum Pressure (bar)
  - 1 bar≈15 psi → 8 bar≈120 psi
- MIE – Minimum Ignition Energy (millijoule)
  - Discharges from human body up to 25-30 mJ
  - Pneumatic conveying up to 1000 mJ

Sample of Data

Product	K_{st}	P_{max} (bar)	MIE (mJ)
Sugar	138	8.5	400-700
Corn Starch	143-202	7.8-10.3	30-300
Coal Dust	152	8.3	60-700
Corn	75/169	9.4/7.8	40
Gluten Meal	116	7.3	50-100
Feed/Bran	67-120	7.3-8.3	300-500
Soy Flour	117	7.4	>500
Wheat Flour	87	8.3	60
Cocoa	62-108	6.5-9.1	120
Cottonseed Hulls	46	7.4	>500
Cellulose	82	8.6	1000-10,000
Citric Acid	100	6.8	> 400,000
Glucosamine	105	10.2	>28,000
Erythritol	255	7.2	4

Why So Dangerous?

- Dust Explosions produce
  - Flame ball over 30 feet long in controlled venting
  - Pressure from air heating up rapidly can be over 150 psig if pressure is contained
  - Both occur in less than 100 milliseconds
- Equipment or enclosures are not rated for the peak pressure that is generated in about 100msec can catastrophically fail resulting in personnel injury and significant property damage.

First Recorded Dust Explosion

- Dec 14, 1785
- Turin, Italy
- Bakery
- Very dry flour
- 2 boys injured

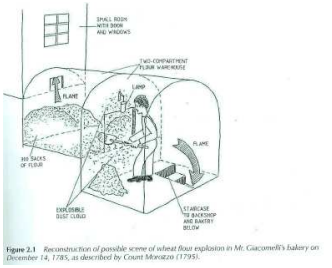


Figure 2.1 Reconstruction of possible scene of wheat flour explosion in Mr. Gacomelli's bakery on December 14, 1785, as described by Count Morozzo (1795).

Cedar Rapids, Iowa

On May 22, 1919, the Douglas Starch Works exploded at about 6:30 p.m. There were 109 men in the plant at the time of the explosion. The pillar of dust and flames shot skyward about 5000 feet and the explosion was felt 30 miles away. Doors were blown open and windows shattered at the Cedar Rapids Country Club three and one-half miles away.

Of the 43 men who lost their lives, 10 bodies were never found, 10 bodies were partially found and buried in a common grave in Linwood Cemetery.

DeBruce Elevator Explosion

- June 8, 1998 near Wichita, Kansas
- 11 people were injured, and seven died

This dust explosion appeared to propagate through almost the entire complex, both in the tunnels below, and the structures across the top of the silos. Almost no part of the elevator was untouched by the explosion. Many of the silos had their tops blown out. A prime example of the force of the explosion was a heavy steel door which covered one of the tunnel entrances, approximately 7 feet by 7 feet, weighing about 600-800 pounds, which was missing. Initially rescue workers wondered where it had gone, until someone looked up...and saw that it appeared to be "shrink-wrapped" into the I beams of the gallery floor 120 feet straight up!

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South end of damaged grain elevator

Imperial Sugar Explosion

- Feb 7, 2008
- 14 Fatalities

Stop at 7:57

http://www.csb.gov/investigations/detail.aspx?SID=6

Dust in the News

Bartlett Grain – Atchison Kansas October 29, 2011

- 6 Dead
- 2 Burn Unit
- 4 Escaped?

FOX NEWS Link

Bartlett Milling– Statesville, NC
April 7, 2013

Flash after turning power back on after repair

One Burn Injury

Aug 13, 2014 Coshocton, OH

Explosion at grain company in Coshocton; photo from WBNS video via CNN

Seven injured. Likely cause was a spark amid the grain dust as several rail cars were being filled with corn

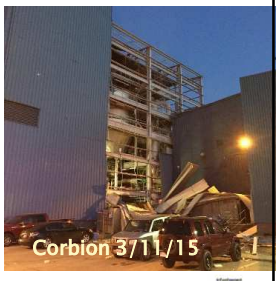
Aug 22, 2014 Evendale, OH

Sept 14, 2014 Flagstaff, AZ
Nestle Purina Pet Food

- 4 Burned
- Maintenance
- No Operators on site
- Flash Fire

Combustible Dust Incidents

- Corbion: Grandview MO
  - Emulsifiers
  - March 11, 2015
  - 3 Injuries
  - Started in Packaging dust Collector
  - Outside walls designed to relieve



More Incidents

- Wrigley-Chattanooga 3-18-15
  - Starch dust collector
  - Explosion and fire

- OK Foods Feed Mill 3/23/15
  - Flash Fire from welding on bin
  - 3 burned
- Vita Line Pet Food- PA 3/31/15
  - Silo explosion after fire
  - No Injuries

...and still more

- Feed mill silo explosion in Netherlands
  - April 13, 2015
- LaPorte County Grain, IN
  - April 16, 2015
  - 4 injured – 2 LifeFlight

- Pilgrim's Pride Chicken Feed, GA
  - Explosion with significant damage

Wood Flour Mills-England

- July 17, 2015
- 3 Explosions and Fire
- 4 Fatalities
- 4 Hospitalized

Simmons Poultry Feed Mill -12/1/15

- Fairland, OK
- Fire smoldered for weeks
- Explosion blew top off silo
- 3 people seriously burned 5 years ago from an explosion and fire

Perfetti Van Melle – 12/4/15

- Airheads Candy
- Erlanger, KY (South of Cincinnati)
- Sugar silo explosion and fire
- 2003 Explosion
  - Maltodextrin
  - Ignited by static
  - 1 person injured

Feed Mill Explosion-Rockmart, GA

- JCG Farms, February 7, 2016
- 1 Fatality plus 5 injuries
  - 1 still hospitalized a week later
  - If during week, 35 vs 8 people on site
- $3 million damage
- ATF: Series of dust explosions
  - Originated at base of concrete tower near receiving area
  - Ignited natural gas line

Hinton IA Grain Elevator

- Central Valley Ag elevator
- March 17, 2016
- Explosion and fire
  - Dump control house in flames
- 2 people severely burned

WestPine MDFB

- Quesnel, BC
- March 9, 2016
- Explosion and fire involve 4 baghouses
- Facility had demonstrated it had a compliant program for management of combustible wood dust

Oregano Explosion

- April 5, 2016
- Spice plant in Reno, NV
- Dust explosion in grinding hopper
- No injuries

Emsland-Stärke (Germany)

- June 7, 2016
- Explosion when workers opened inspection hatch of a mixing machine for corn starch
- 1 fatality

Fish Meal Explosion

- Dutch Harbor, Alaska
- September 19, 2016
- Explosion of fine fish meal
- No injuries

Tate & Lyle

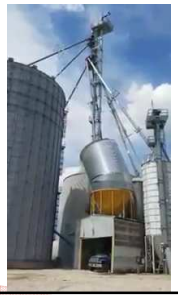
- September 26, 2016
- Francesville, Indiana
- Explosion started in bucket elevator leg
- 2 people severely injured and later died

Didion Milling

- May 31, 2017
- Didion Milling in Cambria, Wisconsin
- Reports of 2 distinct explosions
- 16 employees on site
  - 4 fatalities after first week
  - 12 treated for burns and four extended hospital
  - June 23rd a fifth person died from injuries

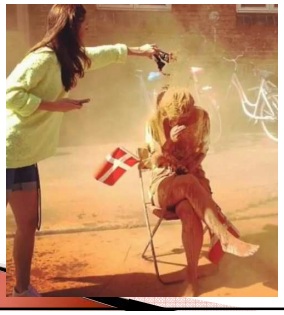
Grain Bin Collapse

- July 31, 2017
- Farm near Switz City, Indiana
- No injuries



Cinnamon Shower?

- Denmark Bachelor Tradition



Are You a Believer?

OSHA®

Regulatory: OSHA

- OSHA 1910-272 Grain Standard Dec 31, 1987
  - Held up as an effective model
- OSHA developing a new standard
  - NEP (National Emphasis Program) Oct 2007 & March 2008
  - Enforcement by using the General Duty Clause
  - OSHA process delayed GHS (Globally Harmonized System) March 2012
  - Dust included as a "Hazardous Chemical"
- The CSB (Chemical Safety Board) designated general dust standard as first "Most Wanted Safety Improvement."

GHS Label Elements

- Hazard: Combustible Dust
- Signal word: Warning
- Hazard Statement: May form combustible dust concentrations in air
- Pictogram: No Pictogram
- Precautionary Statement (possible language):
  - Keep away from heat/sparks/open flames/hot surfaces. – No smoking. Keep container tightly closed. Ground/bond container and receiving equipment. Prevent dust accumulation to minimize explosion hazard.

56

NFPA Dust Standards

- Consensus Standards
- Guidance for Prevention and Mitigation
- RAGAGEP (Recognized And Generally Accepted Good Engineering Practices)
- Great resource
- Not Directly Enforceable by OSHA
  - General Duty Clause

NFPA: Free Access

http://www.nfpa.org/codes-and-standards/free-access

NFPA Standards-Basis for Safety

- Prevent or limit formation of hazardous atmosphere
- Prevent ignition
- Limit the consequences of a deflagration to an acceptable level
  - Including secondary explosions

NFPA Occupancy Standards

- NFPA 652: Fundamentals of Combustible Dust
  - New September 7, 2015
- Industry Specific
  - NFPA 61: Agriculture and Food Processing
  - NFPA 484: Combustible Metals
  - NFPA 655: Sulfur
  - NFPA 664: Wood Processing and Woodworking
  - NFPA 654: Combustible Particulate Solids

Industry Specific Standard Prevails

NFPA Design Standards

- NFPA 68: Deflagration Venting
- NFPA 69: Explosion Prevention Systems
- NFPA 77: Static Electricity
- NFPA 91: Air Conveying
- NFPA 499: Classification of Hazardous Locations
- NFPA 70: NEC (National Electrical Code)
- NFPA 13: Sprinkler Systems
- NFPA 15: Water Spray for Fire Protection
- NFPA 72: Fire Alarm and Signaling

NFPA: DHA (Dust Hazard Analysis)

- Evaluate fire, deflagration, and explosion hazards
- Specific fire and deflagration scenarios
  - ID safe operating ranges
  - ID safeguards in place
- Recommendation of additional safeguards to manage the hazards
- Performed or led by a qualified person
- Documented including action items

DHA Techniques

- Checklist Analysis
- What If Analysis
- What If with Checklist
- HAZOP (Hazard and Operability Analysis)
- LOPA (Layers of Protection Analysis)
- FEMA (Failure Modes and Effects Analysis)

NFPA 652: DHA Retroactivity

- For existing processes undergoing material modification (25% of original cost), DHAs as part of the project
- For other existing processes complete DHAs within a ~~3~~ 5-year period and demonstrate reasonable progress in each of the 3 years
  - NOTE: Originally 5 years

NFPA 652: Hazard Management

- Follow Prescriptive Standards

-or-

- Performance Based Design
  - Risk based
  - Permitted to use in lieu of prescriptive
  - Design prepared by person with qualifications acceptable to the owner/operator
  - Design documented in a format and content acceptable to the AHJ

NFPA 652: Management of Change

Written procedures to manage changes to:

- Process materials
- Technology and equipment
- Procedures and facilities
- Staffing
- Job tasks

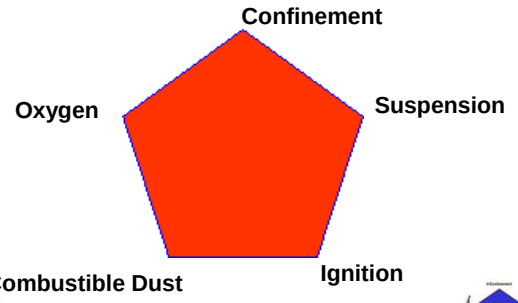
NFPA: Housekeeping

- Included in all NFPA Occupancy Standards
- Housekeeping strategy
- Accumulation depths

FM Global

- 5-1 Elect Equip in Hazardous Locations
- 5-8 Static Electricity
- 7-17 Explosion Protection Systems
- 7-73 Dust Collectors and Collection Systems
- 7-75 Grain Storage and Milling
- 7-76 Prevention and Mitigation of Combustible Dust Explosion & Fire

Dust Explosion Prevention

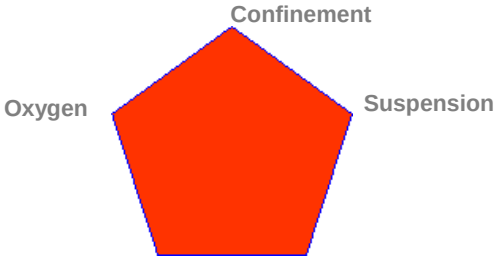


Dust Explosion Prevention

Layers of Protection

Confinement
Explosion Vents
Oxyg
High Humidity
Recycle Flue Gas
Su n
Aspiration
Combustible Dust
Sanitation
Ignition
Ignition Source Control

Dust Explosion Prevention

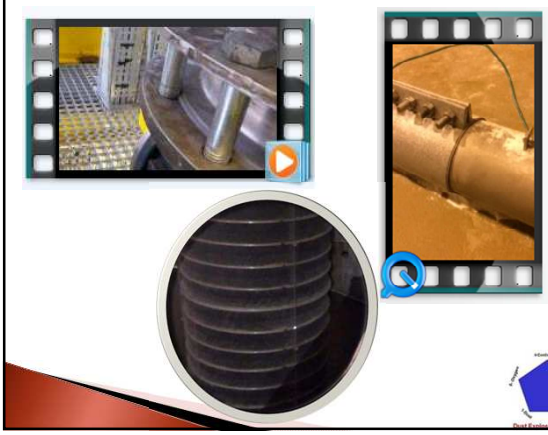


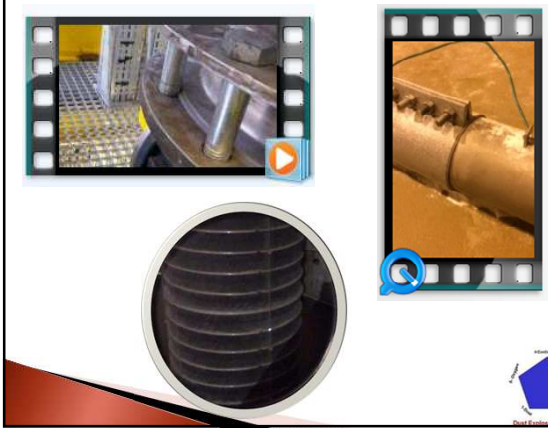
Ignition Prevention System

- No Smoking on site
- Management of Hot Work
  - Welding
  - Cutting
  - Grinding

Ignition Prevention

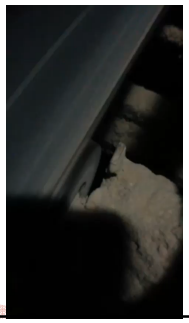
- Magnets to remove tramp metal
- Bonding and Grounding
- Bearing Temperature Monitoring
- Belt alignment switches (rub blocks)
- Belt slow down switch
- Electrical Classifications
  - Class II, Div 1, Group G
    - Dust usually present
    - Rated enclosures
  - Class II, Div 2, Group G
    - Dust not usually present
    - Dust tight enclosures



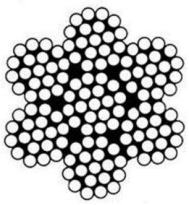


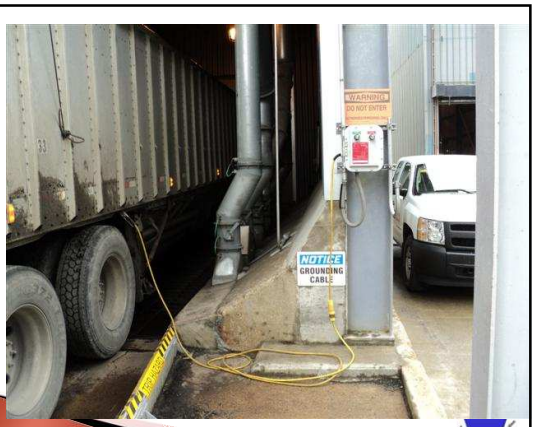
Non SCOF Conveyor Belt

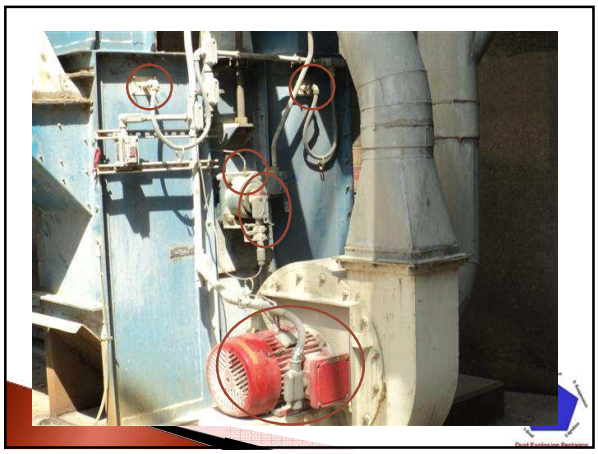
- Static Conductive Oil-resistant Fire-retardant

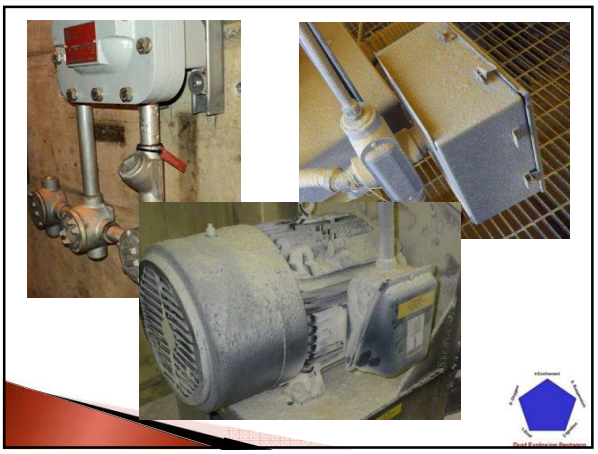


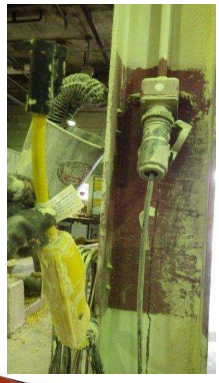
Bonding Wires: Recommend using 19 x 7 stainless steel wire rope. This is distributed by Motion Industries. You can buy this on a spool and then cut to length. Use crimp-on ends for attachment and to keep from fraying.



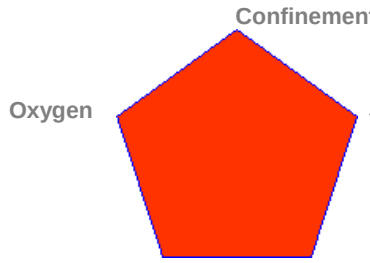








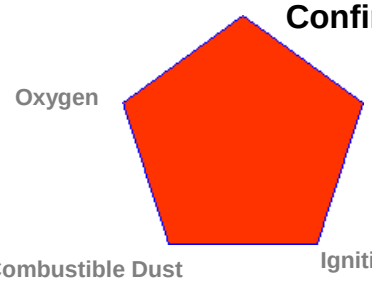
Dust Explosion Prevention



Suspension and Concentration

- Aspiration Systems
  - Big Vacuum Cleaners
  - Reduces concentration inside equipment
  - Reduces dust leakage outside of equipment

Dust Explosion Mitigation



Explosion Protection

- Containment – 10 bar (150 psi) construction
- Explosion Relief Venting
- Explosion Suppression
- Explosion Isolation

Explosion Relief Venting

Explosion Vents

- Low burst pressure
- Wide range of sizes
- Stainless Steel –
  - one piece clean type
  - composite type
  - high temp type
- Replace after use
- Low inertia / fast to open
- No fragmentation
- Open Vent sensor option
- Sized in accordance with NFPA 68 or VDI 3673 or EN 14491:2006

- Brixon Latch

Venting Considerations

- Environment
- Operating Conditions
- Vessel Location
- Vessel Strength
- Interconnections;
  - **Isolate ducting**
- Post Explosion Fires
- Reaction Forces
- **Line of Fire**

Can the flameball be accepted?

Fireball Size

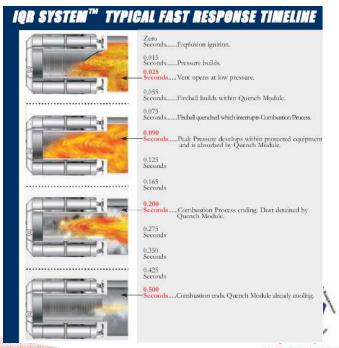
Vessel size (cubic ft)	Fireball with 1 vent (ft)	Vents	Fireball (ft)
10	17	1	17
50	30	2	23
100	37	3	26
500	63	4	40

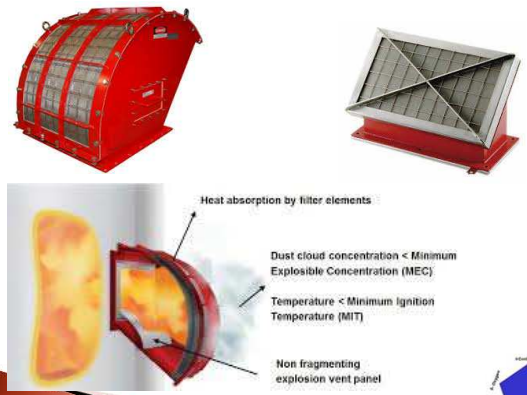
Exposure to Explosion Vents

Q91100BC-001PP

Flameless Vents

Designed for applications where equipment is indoors & safe venting through ducting is not possible or flameball is not acceptable.





NFPA 68- Inspection and Maint

- **5.2.4.1** Deflagration venting shall be regularly inspected and maintained to confirm the ability of the venting to perform as designed.
- **5.2.4.2** Inspection and maintenance shall be documented and retained for at least 1 year or the last three inspections.

ANNUAL INSPECTION FORM

USER CONTACT INFORMATION

Company name: _____ Date inspected: _____

Address: _____ Time: _____

City: _____ State: _____ Zip code: _____

Telephone: _____

Inspector's name: _____

Inspection company: _____

Address: _____

City: _____ State: _____ Zip code: _____

Telephone: _____

Vent ID#: _____

Vent location: _____

Vent manufacturer: _____

INSPECTION

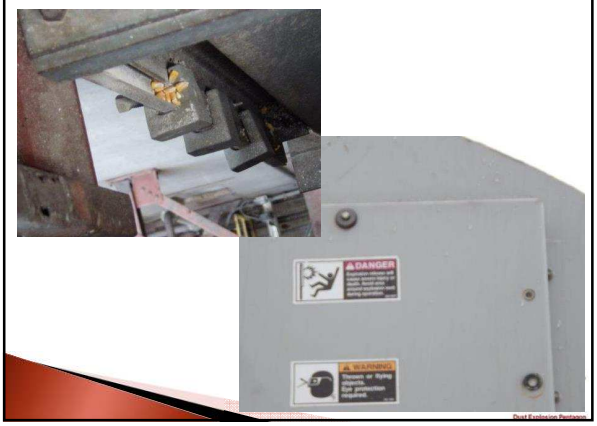
Follow the manufacturer's recommendations and the following:

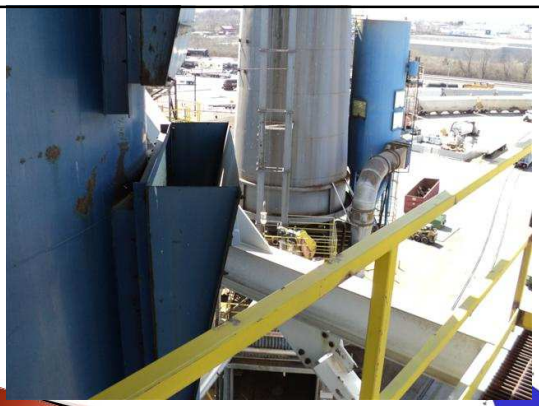
Is the vent:

1. Clear of obstructions? ❑ Yes ❑ No
2. Corroded? ❑ Yes ❑ No
3. Mechanically or physically damaged? ❑ Yes ❑ No
4. Clearly labeled: Warning. Explosion relief device? ❑ Yes ❑ No
5. Clearly tagged/labeled with manufacturer's information? ❑ Yes ❑ No
6. Protected from ice and snow? ❑ Yes ❑ No
7. Painted or coated? (Other than by the manufacturer) ❑ Yes ❑ No
8. Showing buildup or deposits? ❑ Yes ❑ No
9. Bulging, damaged, or deformed (from original shape)? ❑ Yes ❑ No
10. Changed, altered, or tampered with? ❑ Yes ❑ No
11. Showing signs of fatigue? ❑ Yes ❑ No
12. Provided with fasteners and mounting hardware in place? ❑ Yes ❑ No
13. Frame damaged or deformed? ❑ Yes ❑ No
14. Released? ❑ Yes ❑ No
15. Opening sensor operable and wiring up to current codes? ❑ Yes ❑ No
16. Provided with seals, tamper, or other opening indicators intact? ❑ Yes ❑ No
17. Provided with restraints in place and attached? ❑ Yes ❑ No
18. Provided with hinges lubricated and operating freely? ❑ Yes ❑ No
19. Clean and free of contamination? ❑ Yes ❑ No

 NFPA 68 (p. 1 of 2)

FIGURE A.11.4 Sample Annual Inspection Form.

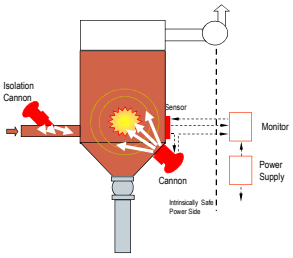




Suppression

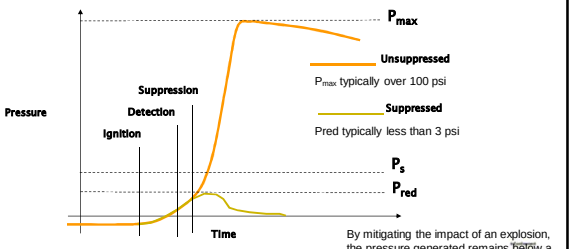
Sequence of Events;

1. Explosion Sensed
2. Cannons Activated
3. Suppression Agent Released Into Process
4. Explosion Suppressed & Burning Material Isolated
5. Process Shutdown



IPD System applied to Dust Collector

How Suppression Protects Equipment



By mitigating the impact of an explosion, the pressure generated remains below a safe level for the process equipment.

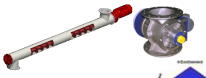
Isolation

Prevent propagation of flame through piping

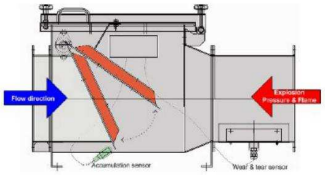
-Mechanical Methods

- Fast acting Knife gate valve.
- Pinch Valve
- Rotary valve of suitable construction
- ~~Screw conveyors with product choke~~

-Chemical Isolation

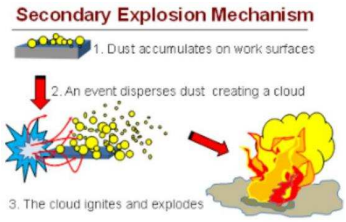


Mitigation: Passive Inlet Explosion Isolation



- Passive Explosion Isolation for Collector Inlet Ducts
- Lower Cost Alternative to High-Speed Valves or Chemical Isolation
- Sensors improve reliability, reduce inspection frequency
- Third-Party Performance-Based Approvals per NFPA requirements

Secondary Explosions



Catastrophic Results

- Building Collapse
- Fatal Burns

Sanitation

- Conditions
  - Can I see my footprints?
  - Can I write in the dust?
  - Can I see the underlying color?
- Cleaning Frequency
  - Before it is unacceptable
  - Procedure in case of upset

Sanitation – Cleaning Methods

- Maintain dust level to < 1/32" over 5% of area
- Exception procedure if exceed 1/8"
- Sanitation Procedure
  - Vacuum
  - Sweep or wash down (not stir up dust)
  - Compressed air to blow down (NOT RECOMMENDED)
    - After other methods used
    - Only for inaccessible surfaces
    - Ignition sources and hot surfaces eliminated
    - Approval process

NOT Recommended

Color Play Asia

- Taiwan Water Park
- June 27, 2015
- 1000 having fun

- Safe, non-toxic
  - Corn Starch
  - Food Coloring
  - NO Heavy Metals
  - NO Lead

Until it finds an ignition source…

- 498 Burned
- 221 Intensive Care
- June 29 – 1st fatality
- July 2 – 2nd death
- July 6 – 3rd fatality

- July 30 – 10th fatality
- Oct 29 – 13th fatality
  - 44 still hospitalized with 11 in intensive care
- Nov 29 – 15 victims
  - Also 2 related suicides

Fire Fighting

- Furniture manufacturing
- Abbotsford, B.C.
- September 12, 2016

Top 3

- 1. Sanitation
- 2. Sanitation
- 3. Sanitation
- The single biggest difference between a small explosion and a disaster
  - NFPA 654:1/32" over 5% of area
  - NFPA 61: 1/8" over 5% of area

Key Take- Aways

- Food dust can be explosive
- Dust explosions can be devastating
- NFPA dust standards
  - Know your dust
  - Scenarios and protection layers
- Secondary explosions are the most dangerous!

Questions?

Demonstration



References

NFPA (National Fire Protection Association)
www.nfpa.org/codes-and-standards/free-access

CSB (Chemical Safety Board)
www.csb.gov

FM Global Data Sheets
www.fmglobal.com

Contact Information

Feel free to contact me with any questions

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