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Fire and Explosion Hazards for Dust, Liquids and Gases

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Profile Summery - Harshad Kalavadiya CIH CSP

Years of Experience : 13^+ years of exposure in EHS

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Academic qualification : B.Sc. (Fire & Safety)
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NCRB 2021 statistics on fire

A total of **8,491** cases of fire accidents were reported in the country during 2021

8,491 incidents of fire accidents caused **injuries to 485** persons and **8,348 deaths** during 2021.

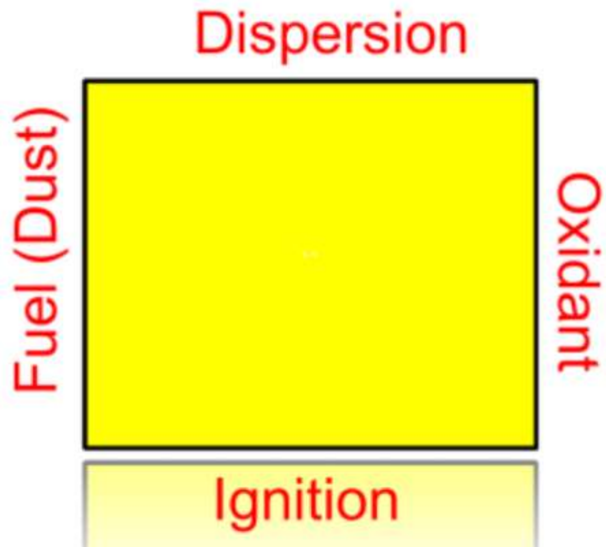
Fire vs Explosion

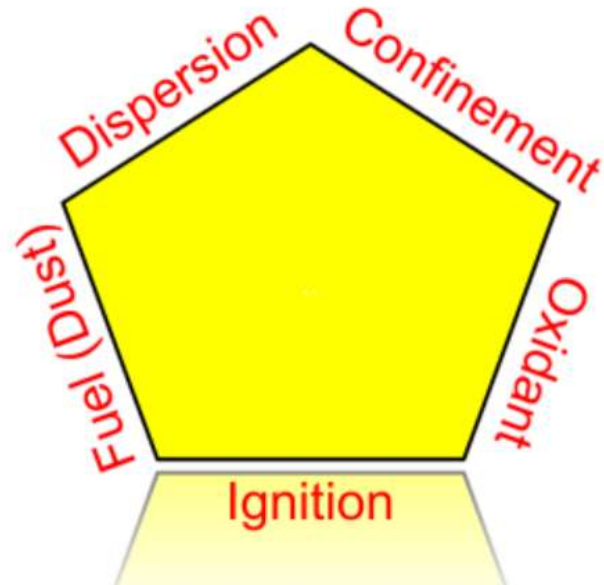
In the first half of 2021, all of the fatalities recorded occurred due to dust explosions. Of the injuries, **89% occurred due to explosions** and 11% occurred due to fires. Some of the more severe incidents include

8,491 incidents of fire accidents caused **injuries to 485** persons and **8,348 deaths** during 2021.

Contents

- Detail understanding of Hazards for Dust, Liquid and Gasses,
- Understanding of common sources of ignition in industrial environment
- Method of classifying Hazardous area context to Indian and international standards
- Guidance of selecting suitable safety measures





Fire, Flash Fire and Explosion

- Normally, three ingredients are a necessary condition for a fire:
  - *fuel, oxygen, & heat.*
- A dust explosion has two additional criteria, *dispersion* and *confinement.*
- If you remove confinement, you still have a hazard for a flash fire.
  - If you remove other legs of these, you remove the hazard.

Attributes of Fire & Explosion

Heat/ Ignition source:		Flame, High temp., Static, Spark generated from compounding/chipping/hammering/friction
Fuel	:	Combustible dust, Flammable liquid (giving up vapor), Flammable Gases, Fibers
Oxygen	:	21% of oxygen in air (when oxygen is above 21% fire burns more quickly)
Dispersion	:	Main cause for the flash fire; sudden intense fire
Confinement	:	Fifth & main factor for the dust explosion

Some useful terminology

Flash Point	:	Lowest temperature at which a liquid produces enough vapor to form ignitable mixture in air
Auto ignition	:	The minimum temperature required for material to catch fire without an outside ignition source
Lower flammable limit	:	Lowest concentration of flammable mixture in air which allows combustion
Upper flammable limit	:	Highest concentration of flammable mixture in air which allows combustion
Limiting oxygen concentration	:	Amount of oxygen below which combustion is not possible

Flammable Vapor

Vapor burns liquid do not.

All flammable liquids share one common characteristics : Vapor they give off during evaporation are flammable.

Vapors can sometimes be seen,

You can also smell many vapors, if you smell liquid in the air there are vapors present.

As temperature increase evaporation increased the amount vapor given off by flammable liquids

Some attributes of Vapor

- **Vapor Pressure** is measured by how fast a liquid evaporates into the atmosphere. The higher the vapor pressure, the faster the liquid will evaporate. It is very important to understand that vapor pressure changes with the temperature of the liquid. So, the same chemical can have different rates of evaporation during day or night, winter or summer.

- **Vapor Density** is the measure of how heavy a vapor is in comparison to air. Vapors with a density greater than 1.0 are heavier than air and will collect at the lowest possible point. Consider that a vapor with a density above 1.0 will flow like water and may travel until it reaches a possible source of ignition.

Gases

Compressed Gas : Any material or mixture having, when in its container, an absolute pressure exceeding 40 psia (an absolute pressure of 276kPa) or 70 degree F (21.1 degree C) or, regardless of the pressure at 70 degree F(21.1 degree C, having an absolute pressure exceeding 104 psia (an absolute pressure of 717 kPa) at 130 degree F(54.4 degree C).

Compressed Natural Gas (CNG) – Mixtures of hydrocarbon gases and vapors consisting principally of methane in gaseous form that has been compressed for use as a vehicular fuel.

Cryogenic Fluid – A substance that exists only in the vapor phase above minus 73 degree C (minus 99 degree F) at one atmosphere pressure and that is handled, stored, and used in the liquid state at temperatures at or below minus 73 degree C (minus 99 degree F) while at any pressure.

Liquefied Natural Gas (LNG) – A fluid in the cryogenic liquid state that is composed predominantly of methane.

Liquefied Petroleum Gas (LP Gas) – Any material having a vapor pressure not exceeding that allowed for commercial propane that is composed predominantly of the following hydrocarbons, either by themselves or as

Classes of flammable liquid

Class A	flash-point > 23°C	The total quantity in possession at anyone (1) place does **not exceed 30 L**.
Class B	flash-point ≥ 23°C to 65 °C	The total quantity in possession at anyone (1) place does not exceed 2,500 L and none of it is contained in a receptacle exceeding 1,000 L in capacity.
Class C	flash-point ≥ 65°C to 90 °C	The total quantity in possession at anyone (1) place does not exceed 45,000 L transported or stored.

Combustible solid particulate

Combustible Solid Particulate: any solid material composed of distinct particles or pieces, regardless of size, shape or chemical composition, that when processed, stored, or handled in the facility has the potential to produce a combustible dust.

Combustible Dust: a finely divided combustible particulate solid that presents a flash fire hazard or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations.

Combustible Powders: particles of matter intentionally manufactured to a specific size and shape. Typically, powders are less than 1 millimeter and can be elemental or alloy in composition and regular, irregular, spherical, sponge, granular, dendritic, or nodular in shape.

Coal Dust Explosion at Thermal Power Plants Kills Three, Injures Three

Date: January 20, 2021
Location: Angren, Tashkent Region (Uzbekistan)
Address: Nurabad

Type: Dust Explosion

Fuel: Coal Dust
Industry: Thermal Power Production
Equipment: Unknown

Company: Angren Thermal Power Plant
Database Incidents: None Recorded

Loss: Three Dead, Three Injured
Capital Cost: Unknown

Status: Open
Confirmation: Unconfirmed

Company Description:
Angren Thermal Power Plant does not appear to have a website, but its JSC profile states that it is one of the largest power plants in Central Asia, with a capacity of 2,100 MW. Construction of the station began in 1976

According to the Uzbek Emergency Situations Ministry, three people were killed and three others injured when a mixture of coal dust and air caused an explosion at around 11:42 a.m. All of the victims were employees carrying out routine maintenance work.

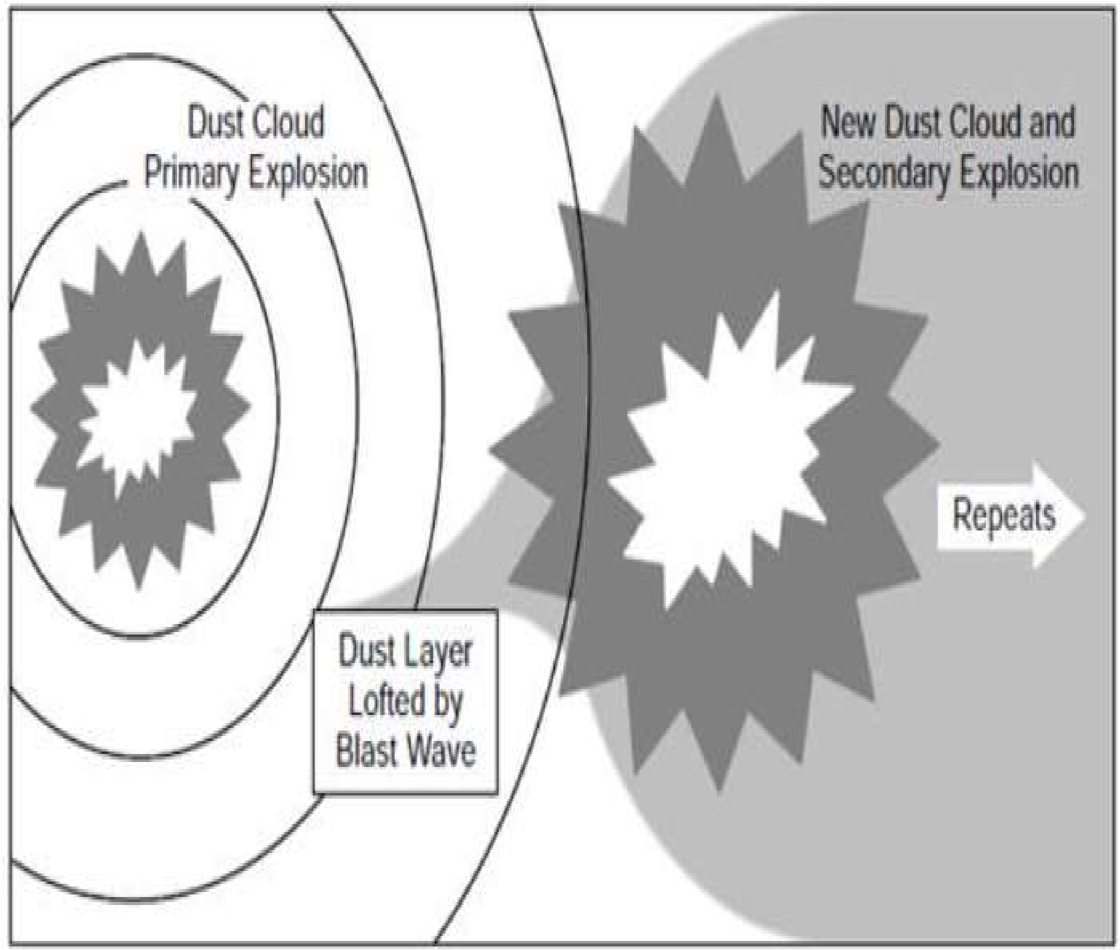
What is explosion?

An explosion is a rapid expansion in volume associated with an extreme outward release of energy, usually with the generation of high temperatures and release of high-pressure gases.

- Explosion are of two types
- 1. Detonation
  - Are characteristics of combustible dust
  - Are extremely fast
  - Destructive force cannot be easily controlled or vented
- 2. Deflagration
  - Are characteristics of flammable liquids
  - There is fast release of tremendous amount of energy but not as fast as detonation
  - Can be vented through explosion relief devices towards open spaces to protect workers and equipment

Primary and Secondary Explosions

Typically, an initial explosion occurs in a limited area (e.g., inside a conveyor, hopper, or bin) where an explosible cloud is present. The overpressure or blast wave from such an event can often cause free flammable adjacent to the initial explosion site to become lofted to generate a new flammable material cloud with an explosible concentration. Often the flame front from the initial explosion serves as the ignition source for a new and frequently larger, secondary explosion, which in turn generates a new blast wave to repeat the cycle. Eyewitness testimony from many large dust explosions has documented that this cycle can be repeated eight times or more and result in near total destruction of a facility.



Explosion at Singapore Fire System Manufacturer Kills Three Workers

Date: February 24, 2021
Location: Tuas, West Region (Singapore)
Address: 32E Tuas Avenue 11, 636854

Type: Dust Explosion

Fuel: Potato Starch
Industry: Fire Protection Systems
Equipment: Mixer

Company: Stars Engrg
Database Incidents: None Recorded

Loss: Three Dead, Seven Injured
Capital Cost: Unknown

Status: Open
Confirmation: Unconfirmed

Source: Google Maps

Company Description:
According to its website, Stars Engrg is a registered L3 contractor with BCA Singapore in Fire Protection Works and L1 contractor with BCA Singapore for Electrical Works. It was founded in 2010 and offers services that include supplying, designing, installing and maintaining all types of fire protection and electrical systems.

Incident Description:

Through investigating loss history at the facility, physical evidence and witness statements, the committee concluded that **an initial rupture of the oil jacket around the mixer in question released an oil mist which ignited causing a primary catastrophic explosion at the site. Secondary flash fires** also occurred which were likely due to combustion of potato starch powders which were allowed to accumulate at the worksite.

Ignition Sources for Dust Explosions

There are numerous potential sources for ignition in a dust explosion. The most common include:

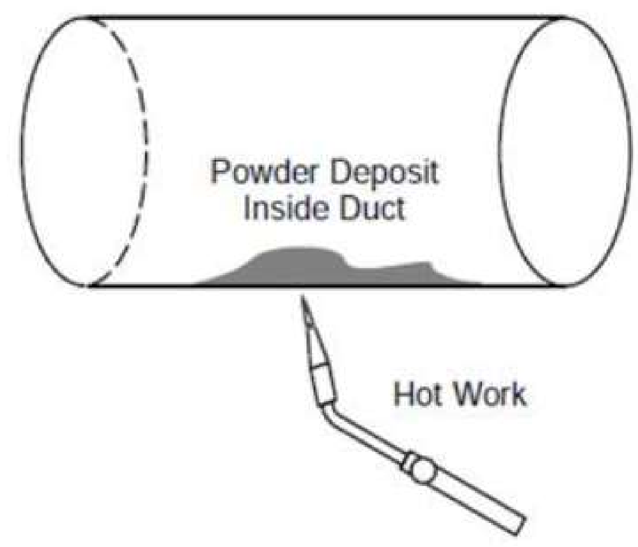
- Open flames (e.g., welding, cutting, grinding, smoking material)
- Smoldering or burning powder (e.g., spontaneous combustion, previous ignition)
- Friction (e.g., hot bearings, rubbing surfaces)
- Hot surfaces (e.g., process equipment, heaters, light fixtures)
- Impact (e.g., grinding, falling objects)
- Electrical discharges (e.g., sparks, arcs)
- Electrostatic discharges (e.g., static sparks)

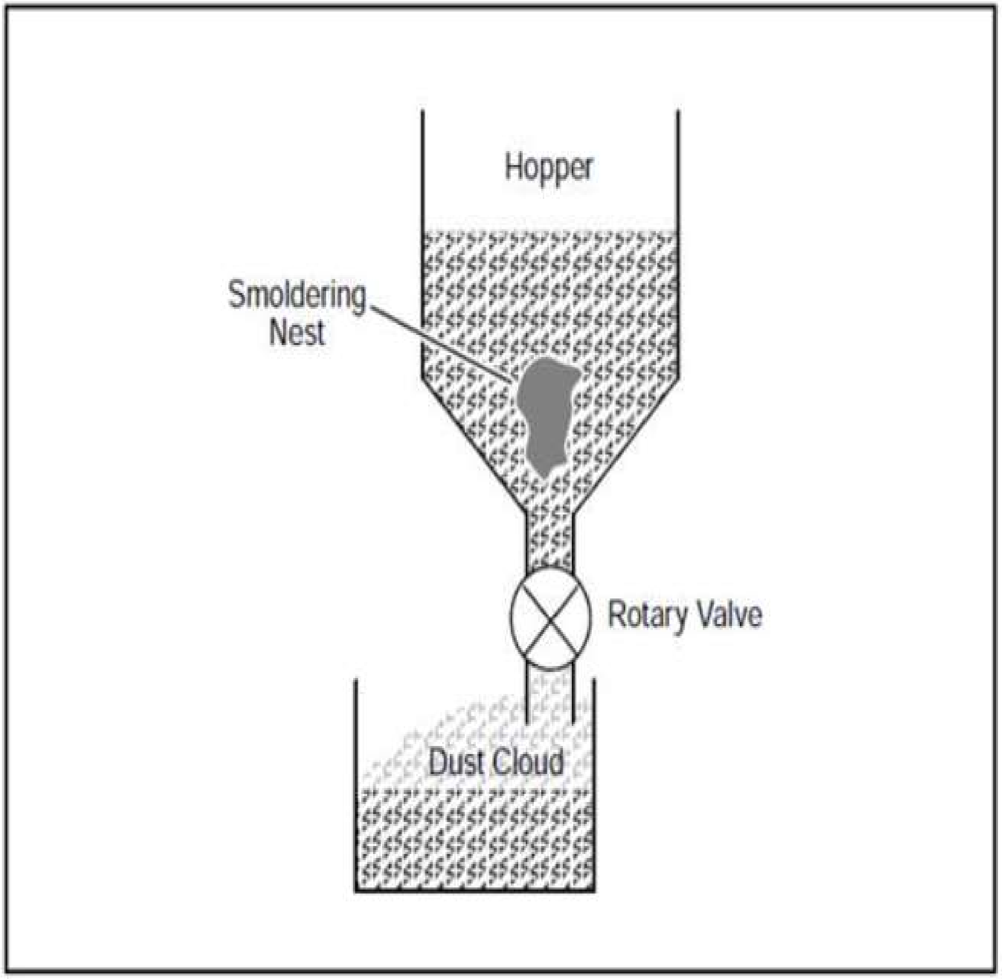
Open Flames

Welding, cutting, grinding, and smoking materials are all energetic enough to provide ignition for dust explosions.

Care is required when any spark producing activity or hot work is performed on processes that may contain powders.

A documented Hot Work Permit system should be implemented and enforced in any area where powders are used or stored.





Smoldering or Burning Powders

When powders are allowed to accumulate in layers and piles, experience has shown that high temperatures can develop from spontaneous combustion or from accumulated heat from hot material introduced into the pile.

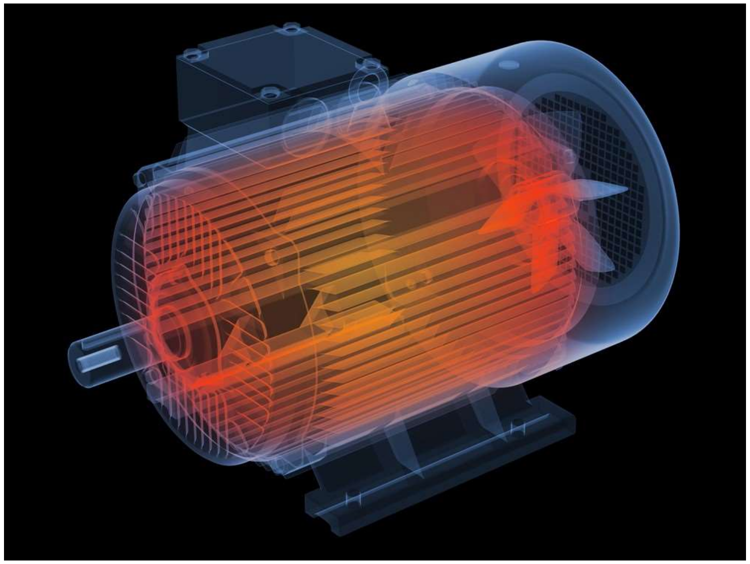
Friction

Friction is often an unintended source of ignition for explosions. Mechanical failure (e.g., failed bearings or misaligned equipment parts rubbing together) can generate a significant amount of heat, often in a relatively short time. Elevated temperatures created by friction can cause ignition of surface powder layers or other combustibles that can cause a secondary ignition in a nearby dust cloud. Powder entering a bearing through a failed or ineffective seal is a frequent source of overheating and ignition for fires and explosions.

Regular inspections and preventive maintenance can detect and prevent friction heating. Where friction heating can be reasonably anticipated, it may be necessary to manage another of the critical factors (e.g., the oxidant) of dust explosions in order to assure a safe process

Hot Surfaces

Hot surfaces are often a reality in process operations. Heaters, dryers, motors, light fixtures, and other such equipment normally operate at elevated temperatures. Proper electrical classification in powder handling areas can help assure that normal surface temperatures will not exceed safe levels.



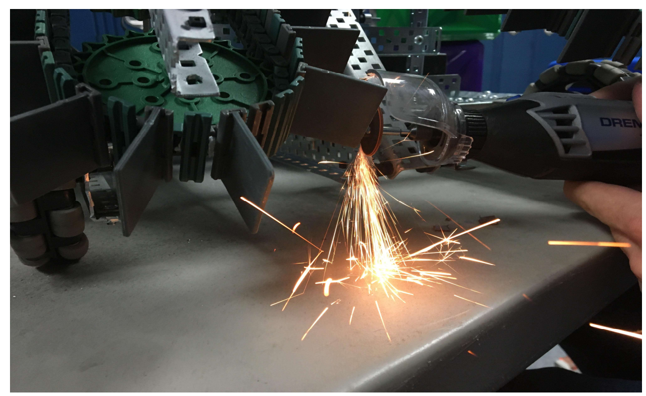
Other heated equipment (e.g., ovens, dryers and process vessels) may develop surface temperatures high enough to create potential ignition sources, especially if a powder layer that can serve as insulation is allowed to accumulate.

In addition, many hydrocarbon resins used in common processes are known to degrade when subjected to prolonged periods of elevated temperatures, often causing a lowering of the autoignition temperature, which may increase the potential for ignition.

Impact

Energy released from incidental impacts (e.g., striking of tools or other objects against hard surfaces) is not likely to be of concern as a source of ignition for a explosion unless rare conditions exist (e.g., a thermite reaction [aluminum and iron oxide] or an unusually sensitive powder).

High energy impact activities (e.g., hammer mills and grinders) can produce enough energy to provide ignition for a dust explosion, especially if accumulated heat from such processes is not adequately managed. In some instances, equipment malfunction (e.g., misaligned conveying equipment) can cause repeated impacts at a fixed location that can eventually get hot enough to ignite an explosible dust cloud.

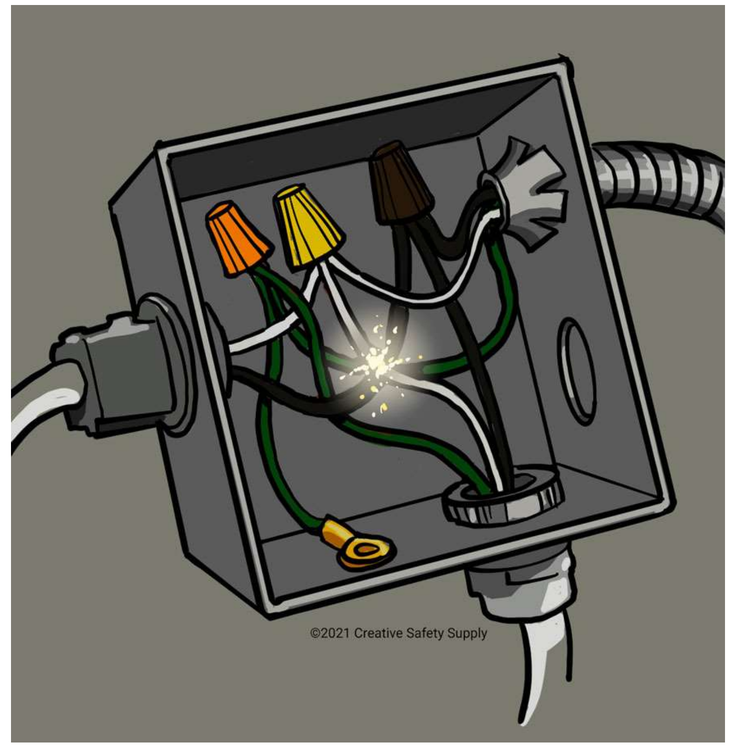


Electrical Arcs and Sparks

Open electrical arcs at common voltages in process operations can easily provide enough energy for ignition of a dust cloud. Stray electrical currents can also result in arcs that release enough energy to cause ignition. Proper classification of electrical equipment and devices used in areas where powders are handled is essential to managing ignition hazards.

Electrical panels, control boxes and other enclosures that house electrical apparatus that cause sparks (e.g., switches, circuit breakers, motor starters) need to be sealed to prevent accumulation of powders inside the enclosures.

All equipment used in areas where powders are handled or stored need to be effectively grounded.



Chemical Ignition sources

Exothermic reaction, by experience we have seen common manufacturing process produces heat on chemical reaction and the controls devastate to control such elevated temperature may abruptly fail to contain under the normal operating temperature range.

Vigorous oxidizing reaction, a type of chemical reaction that involves a transfer of electrons between two species and combines with oxygen are so rapid and uncontrol can produce the enough heat to ignite flammable and combustible vapors and gases.

Exothermic Polymerization, often been seen that when polymerization is happening it occurs with the energy release with might be sufficient for the ignition of flammable mixture present is the area.

Exposing pyrophoric Substances (sodium metal) to air, potassium hydride and white phosphorus are few such example of substances that spontaneously ignitewhen exposed to air.

Use of non-rated electronics

Equipment and devices must be rated to use in flammable and classified areas;

Some commonly used electronics are;

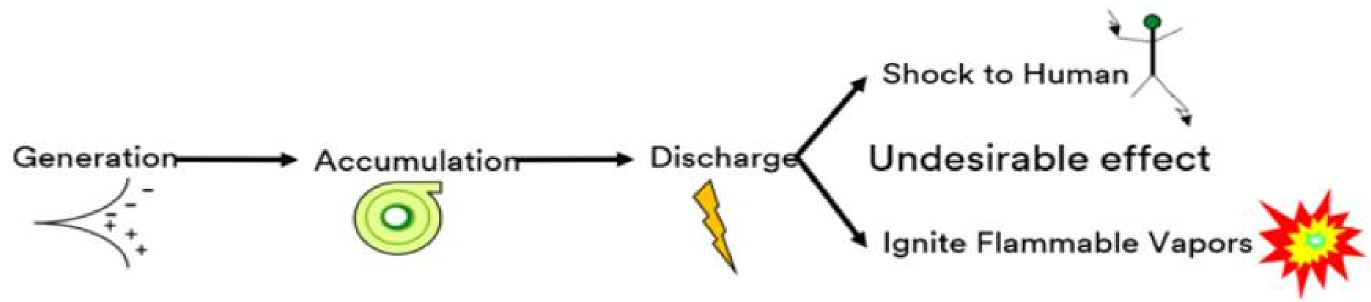
- Pagers & two ways radios
- Cameras and video equipment
- Test equipment
- Cell phones
- Laptops, Tablets,
- Flashlights

Electrostatics and Dust Explosions

Static electricity is a frequent cause of ignition of explosible powders. Management of static electricity is a major concern in the design and operation of powder handling systems and processes that use combustible and explosible powders.

The four ingredients of the static hazard for fire and explosion are:

- Generation of static electricity
- Accumulation of electrostatic charges
- Electrostatic discharges to ground or an object of opposite electric potential
- Ignitable mixtures



Electrostatics and Dust Explosions

Examples of contact and separation in powder operations include:

- Sliding of a powder down a chute or hopper
- Impact of powder particles against the wall of the conduit in a pneumatic conveying system or in process machinery
- Interaction of powder particles in a bulk stream as material is poured or conveyed

Examples of creation of new surface area in powder operations may include:

- Grinding or pulverizing operations
- Crushing or breakage of powder particles during handling, conveying, and mixing operations
- Breakup of particle clusters

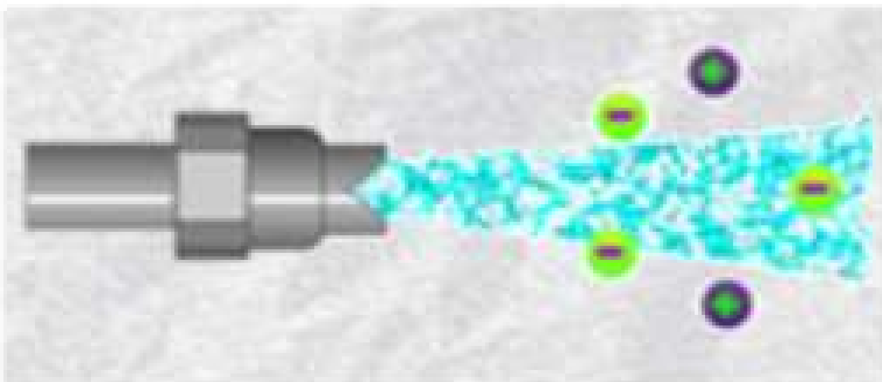
Electrostatics and Dust Explosions

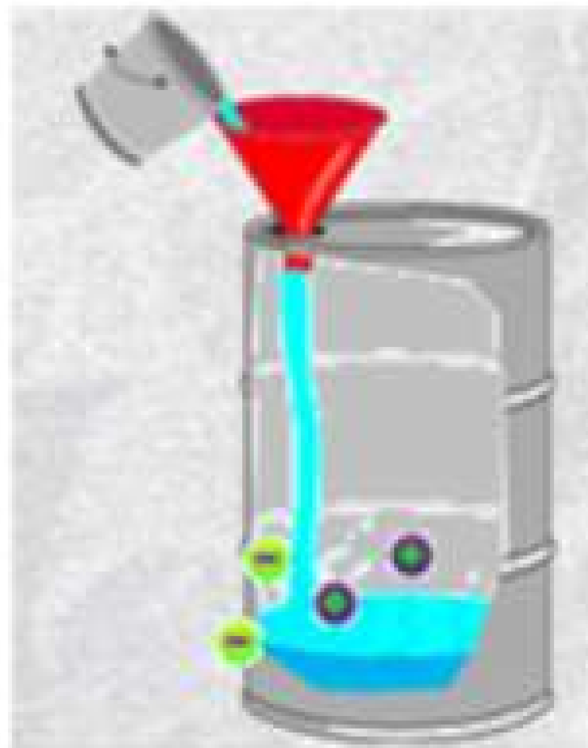
When working with solids or powders (e.g., rubber pellets, resin flakes or pellets) or the many types of powders that may be added into a process operation, static can be generated by:

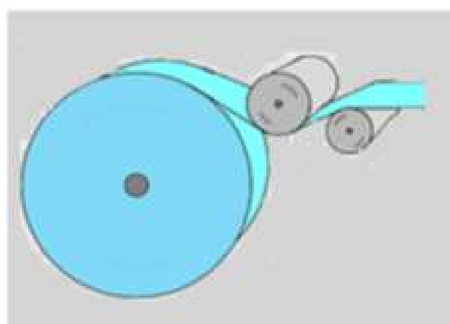
- Shoveling materials
- Sliding materials down a chute
- Cutting or grinding materials
- Rubbing of materials on hoses or piping used in pneumatic or vacuum conveyor systems

The greatest opportunity to manage electrostatic hazards lies with in preventing or limiting the accumulation of a static charge before it can reach a level where the discharge energy is enough to cause ignition.

Common examples of static generations





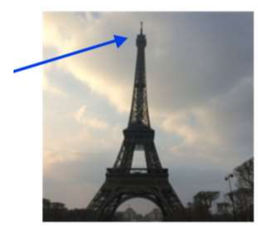


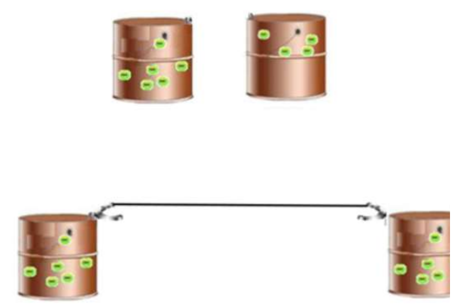
Level of static and effects

1500 volts	Noticeable
2000 volts	Attract the dust
3000 volts	Felt on end of fingers
5000 volts	**Ignites common solvent** (max level of volts for flammable solvent)
10000 volts	Human Shock
25000 volts	**Involuntary human reactions** (max level of volts for in-flammable solvents)

Static characteristics

- The earth is electrically charged, static will seek a path to ground, much as lighting does.
- A grounding clamp uses the same principals as lighting rod; it provides a path into the earth for the electrons to travel.
- Static is also attracted to opposite electrical potential charges and when attempt to equalize will discharge dangerous spark.
- To avoid such situation bonding wire to equalize the charge in control manner.





Factors affecting static charge generation

Contact : Force, Area, Length of contact time or speed

**Speed of separation : **Line speed, Mixer speed, Flow velocity

Conductivity of Materials : Triboelectric series

Static and conductivity

There are two classes of material

- Conductors

  Allows electrons to freely move

  e.g. MEK, Metals, Alcohol

- Non-conductors (insulators)

  Resist flow of electrons (electrons are hold tights)

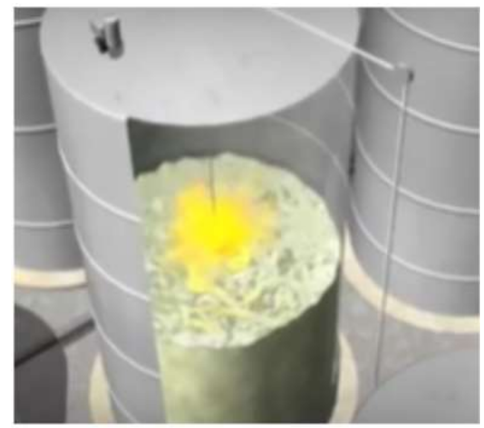
  e.g. Plastic, Teflon, Toluene, Heptane

Discharging of static charge

Once static charge has been generated as result of contact and separation of two material, the charge must be able to accumulate before it can have an effect.

Conductors allow the charge to flow (if grounded)

Non-conductors (insulators) hold the charge



Triboelectric series

As the distance between two material in the series becomes greater, the amount of the charge becomes larger.

- Example 1 : Amount of charge between copper and rubber (small)
- Example 2 : Amount of charge between the human body and silicon (large)

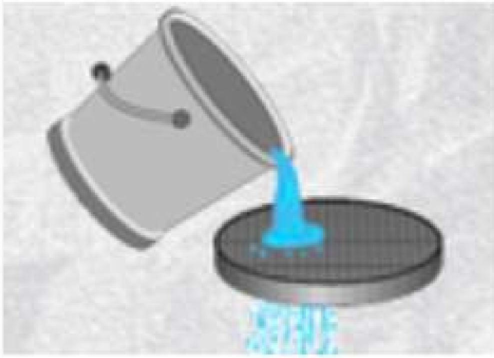
Example of Generation

Solids

- Powder sliding on a chuting or scoop of falling into a container
- Impact with walls in pneumatic conveying
- Grinding
- Web moving over the rolls on a coating line

Liquids

- Spraying
- Splashing
- Blending / mixing / agitating
- Fine Filtering
- Transferring through a pipe



Methods to reduce / prevent static accumulation

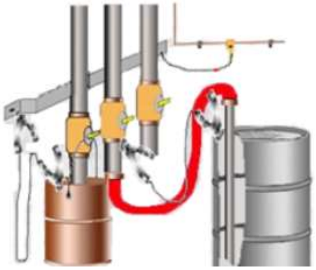
Liquids

Additives

Relaxation Time

Process Modifications

Bonding & Grounding



Methods to reduce / prevent static accumulation

Solids

Bonding & Grounding

Relaxation Time

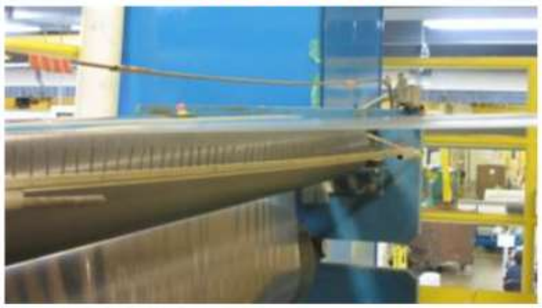
Material Selection

Powered Ionizers

Methods to reduce / prevent static accumulation

Webs

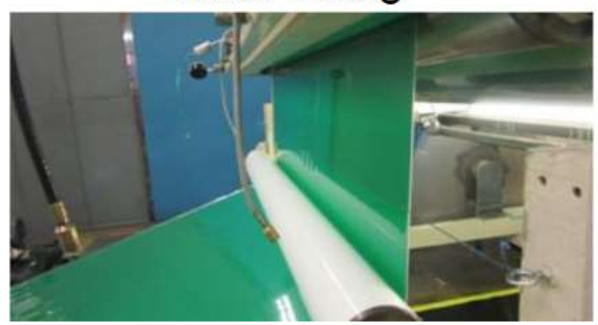
Needle Bars



Tinsel

Powered ionizers

Static String

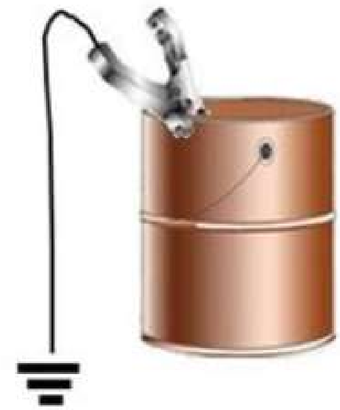


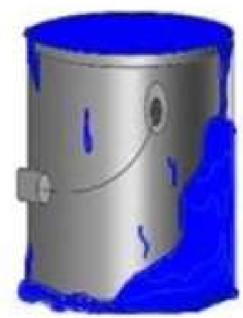
Discharge of static

- The third component of static hazards is the discharge of the accumulated static charges.
- A conductive metal container will quickly dissipate a static charge to ground, if it is grounded.

But

- If the container is not grounded such as if it were on plastic sheet or cardboard, a conductive container will hold onto the static charge. The static can discharge as a spark. This discharge can also occur if the ungrounded container suddenly comes in contact with the ground.





Grounding Nonconductors

- Nonconductors will not dissipate their static charge as quickly as a conductor. Therefore, grounding nonconductors does not ensure a static hazard will be relieved.
- Grounding may relieve some of the static charge from a nonconductor, but usually only from a small area, and at a very slow pace.
- A Potentially hazardous charge may still be present, and nonconductors can contain more than enough energy to ignite the vapors of flammable liquids.

Undesirable effects of Static Electricity

Fire / Explosion
- Cause sparks that can ignite flammable liquids

Personnel safety Hazard
- Cause shocks that can lead to :
- Discomfort
- Injuries
- Potential fatality

Reduce Product Quality
- Attract dust and dirt
- Cause coating defects
- Damage product

Impede Production
- Limit processing speeds
- Damage the equipment

Electrical System

Electrical equipment has a potential to generate a spark when switching on and off. When this occurs in a flammable atmosphere, that spark can be an ignition source.

- Electrical equipment in non-hazardous locations is considered general purpose.
- Hazardous location are areas where flammable atmospheres are present. To prevent sparks from occurring, the electrical equipment has to be rated for either classified or zone areas.

Hazardous area classification

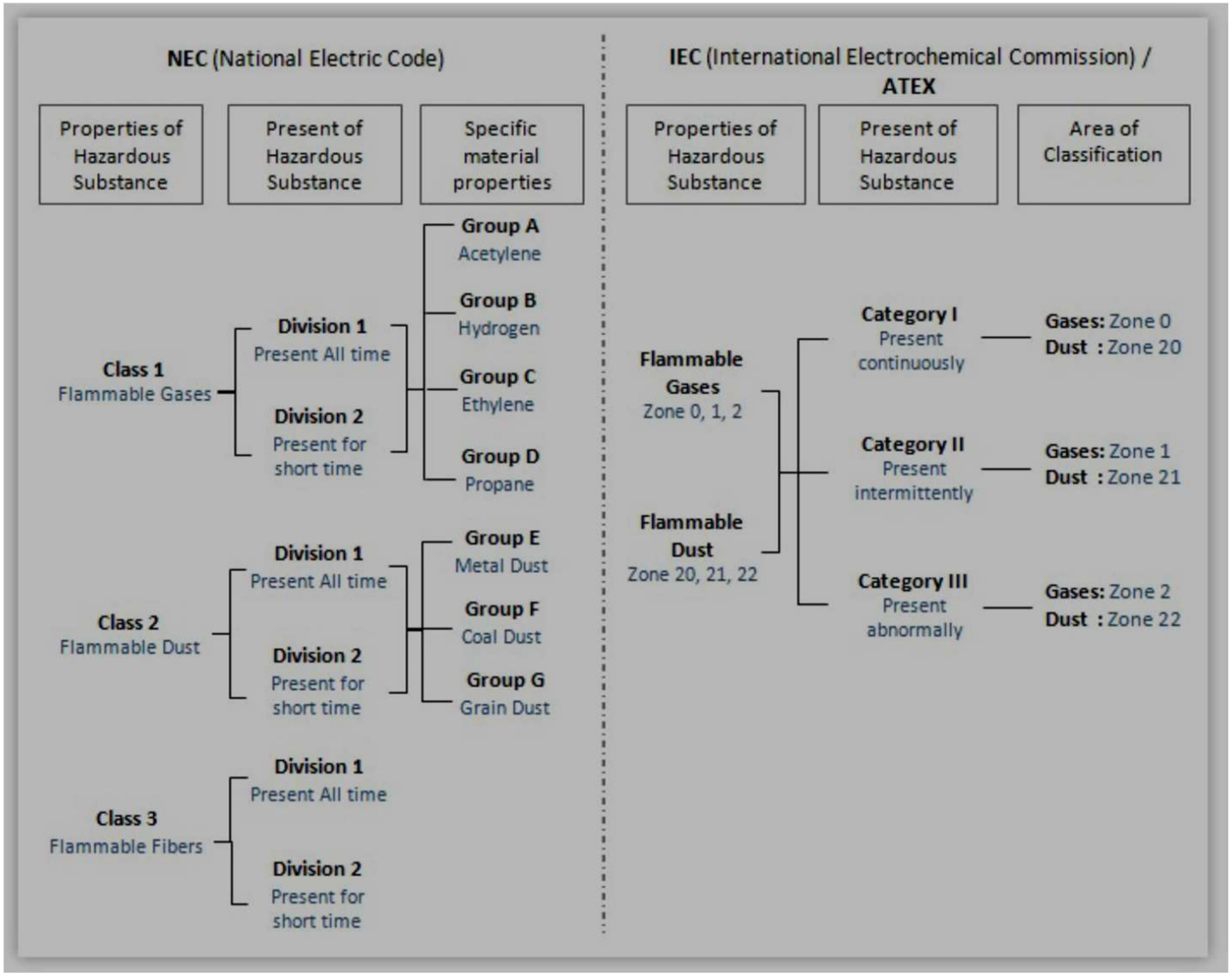
- Guides us for the selection of appropriate electrical fittings and equipment

- There are two parallel Methods being followed in industries
  1) National electrical code (NEC)
  2) International electrochemical commission (IEC) / ATEX (IS 5571 /72)

- Classification in both the method are based on whether the hazardous atmosphere is present or not and reduce source of ignition in flammable atmosphere.

Area classification chart

- NEC –USA
- ATEX - European



Detail interpretation

Zone 0 : An area place in which explosive atmosphere is present continuously of for longer period or frequency.

Zone 1 : An area in which an explosive atmosphere is likely to occur in normal operation occasionally

Zone 2 : An area in which an explosive atmosphere is not likely to occur in normal operation but if id does occur, will persist for short period only.

Match the to correct interpretation

1 : Vapor space above closed process vessels, storage tanks or closed containers, area containing open tanks of volatile, flammable liquid.

2: The flammable vapor can be conducted to the location as through the trench's pipes or ducts.

3 Flammable atmospheric concertation is likely to occur frequently because of maintenance, repair or leakage

4: Failure of process, storage or other equipment is likely to cause an electrical system failure simultaneously with release of flammable gas or liquid;

a) Zone 0 : An area place in which explosive atmosphere is present continuously of for longer period or frequency.

b) Zone 1 : An area in which an explosive atmosphere is likely to occur in normal operation occasionally

c) Zone 2 : An area in which an explosive atmosphere is not likely to occur in normal operation but if id does occur, will persist for short period only.

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1 : Vapor space above closed process vessels, storage tanks or closed containers, area containing open tanks of volatile, flammable liquid. **a)**

2: The flammable vapor can be conducted to the location as through the trench's pipes or ducts. **c)**

3 Flammable atmospheric concertation is likely to occur frequently because of maintenance, repair or leakage. **b)**

4: Failure of process, storage or other equipment is likely to cause an electrical system failure simultaneously with release of flammable gas or liquid; **b)**

a) Zone 0 : An area place in which explosive atmosphere is present continuously of for longer period or frequency.

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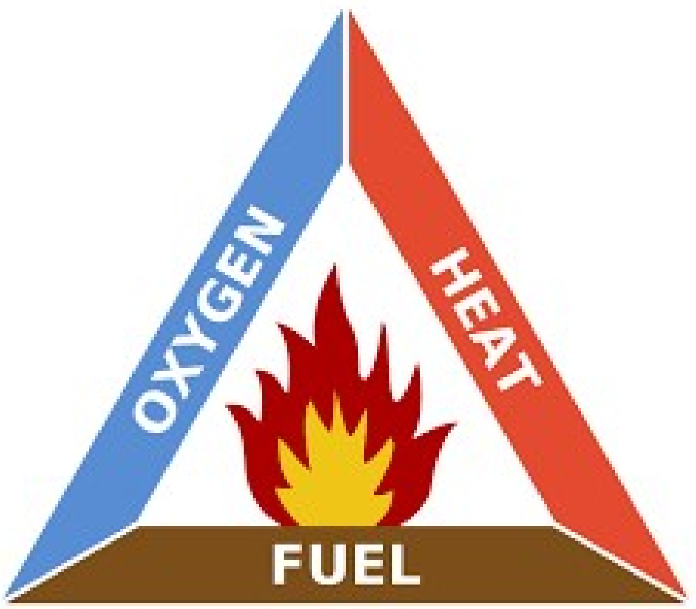
c) Zone 2 : An area in which an explosive atmosphere is not likely to occur in normal operation but if id does occur, will persist for short period only.

Match the methods to basics of fire prevention

Methods by Design and/or Manufacturing

- Intrinsically Safe (lacks energy to spark)
- Purged (air displaced with safe gas)
- Explosion-Proof (will contain explosion)

- Hermetically Sealed (air tight)
- Non-Incendive (arc lacks enough energy)
- Non-Sparking (won't normally spark)
- Oil Immersion (electronics are submerged)
- Purged (same as above, but less checking)



Method of Protection

Methods by Design and/or Manufacturing

- Intrinsically Safe (lacks energy to spark)
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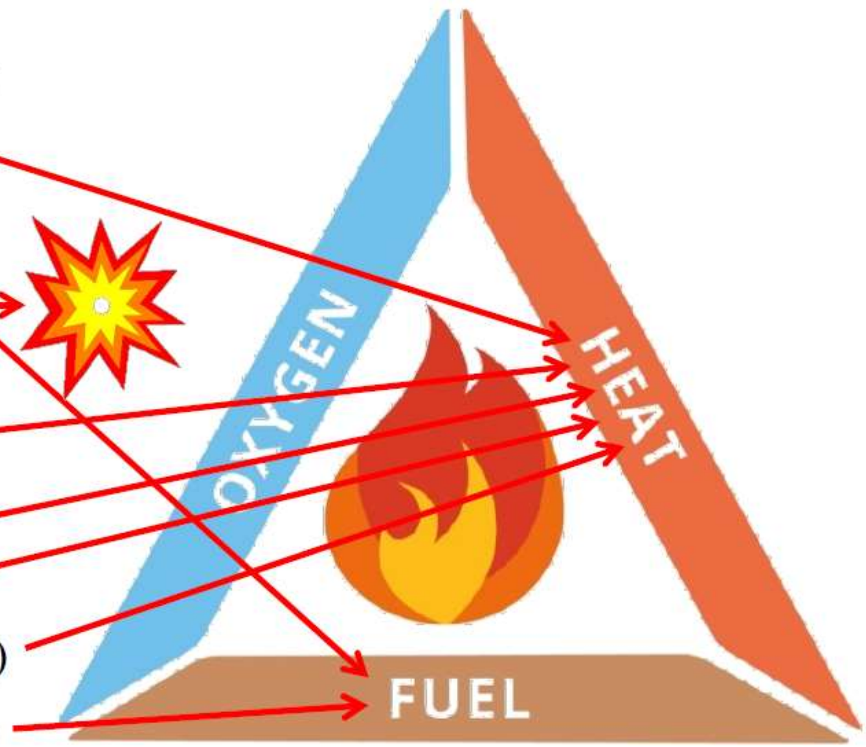
- Oil Immersion (electronics are submerged)
- Purged (same as above, but less checking)



Control strategy - PSM

Organization should develop comprehensive process hazard management program based on the risk extent and organization's risk tolerance;

Fire at Animal Feed Manufacturer Causes Over $2 Million in Damage

Date: March 4, 2021
Location: North Java, New York (USA)
Address: 1830 Perry Road, 14113

Type: Dust Fire

Fuel: Grain Dust
Industry: Animal Feed Production (Agriculture)
Equipment: Grain Machine

Company: Reisdorf Brothers, Inc.
Database Incidents: None Recorded

Loss: No Injuries
Capital Cost: $2,000,000 USD

Status: Open
Confirmation: Unconfirmed

Source: Google Maps

Company Description:
According to its website, Reisdorf Brothers, Inc. is an animal feed mill and farm store located in North Java, New York. It was founded in 1912 and sells feed, supplements and fertilizers, along with its own Country Magic brand of dog and cat foods.

Incident Description:
On March 4, 2021, the Daily News reported a fire at an animal feed mill and farm store in North Java, New York.

The fire was reported at around 7:30 a.m., when a passer-by saw smoke and called 911. More than 14

According to the Wyoming County Fire Coordinator, a mechanical issue caused the fire to ignite in a machine before moving into a wall. It went out the vent pipes and got into a feed silo.

As part of PSI

- Organization must screen all the raw material, intermediate and products on flammability criteria.

- Flammable and combustible material to be screened out from nonflammable material and details of PSI to be maintained based on available data of flammable/comestible material

- Specific Parameters should be tested if not available to support PSI information and MIQA

Non-Combustible Determination

Inherently Noncombustible

- 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. Included are stable oxides (e.g. sand, limestone, Portland cement) as these do not pose combustible dust hazards.

- The material will not burn in air when exposed to 1500°F (815°C) for 5 minutes (i.e., NFPA 704 criterion for Flammability Rating of zero)

Conscious decision

Cost involves

Decision of the future assessment and controls relayed

Go and No-Go based on

*If greater than **95% by weight is larger than 35 mesh (500 micron)** then there is no potential for accumulation (e.g. dust collector) of finer material unless the finer material (e.g. silicate talc) is itself noncombustible, **the concentrations and conditions do not create an explosion hazard**.*

Sample preparation

The particle size and moisture content significantly impact the dust test results:

- **Test Methods Require**
- Moisture content, < 5%
- Particle size, less than 75 mesh (200 um)
- Represents worst case scenario

Minimum Ignition Energy, MIE (mJ)

- Lowest capacitive spark energy capable of igniting a dust cloud
- Ignition Management – Electrostatic ignition hazard
- Defines SD shoe requirements – MIE less than 30mJ require SD

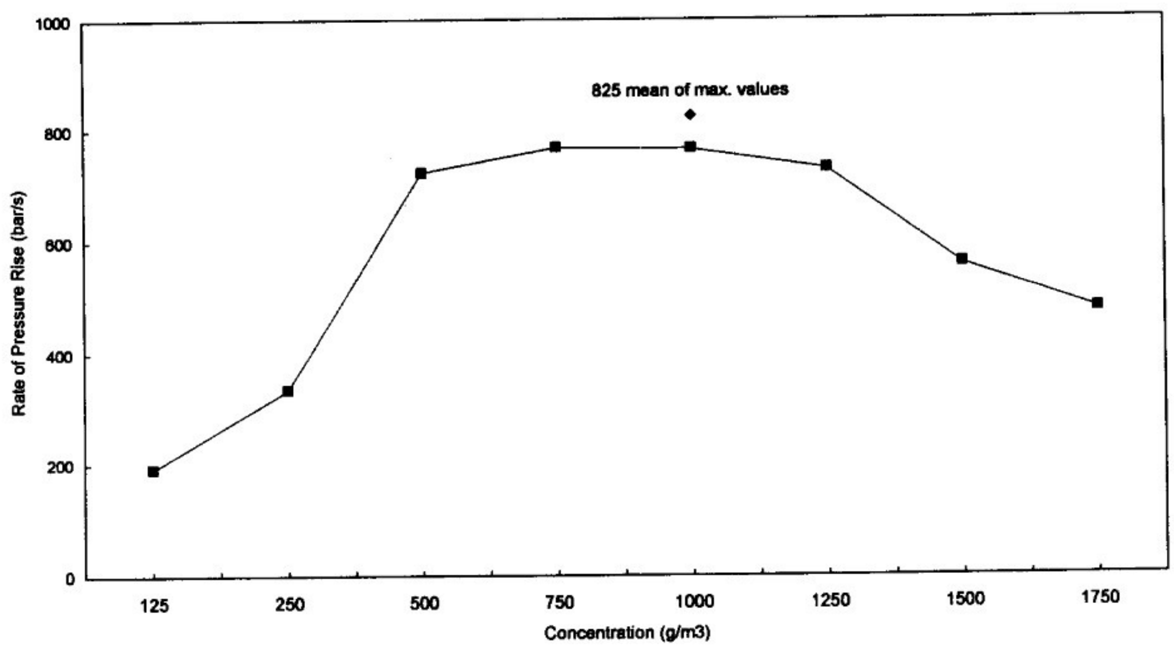
Deflagration Index, Kst (bar-m/sec)

- Measure of how fast the pressure from a deflagration rises in an enclosed vessel
- Used to size explosion vents and design explosion suppression systems.
- Grouped into hazard classes

Dust Explosion Class	Kst (bar-m/s)	Characteristic
St 0	0	No explosion
St 1	> 0 and < 200	Weak explosion
St 2	201-300	Strong explosion
St 3	>300	Very strong explosion

Maximum Pressure, Pmax (Bar)

- Maximum explosion pressure measured for a dust cloud at is most optimal concentration.
- Used to size explosion vents sizing, explosion suppression design and explosion containment design



Other Tests to Consider

- Minimum Explosion Concentration, MEC (g/m^3)
- Determines the minimum concentration of a dust-air mixture that will propagate a deflagration
- Understanding the amount of material needed for an explosion
- Concentration Control
- Used to determine Fireball radius

Other Tests to Consider

Minimum Auto Ignition Temperature, Cloud, MAIT (°C)

- Lowest surface temperature capable of igniting a dust cloud
- Helps in evaluating ignition sensitivity
- Used for defining the maximum operating temperature for electrical and mechanical equipment used in dust environments

Layer Ignition Temperature, LIT (°C)

- Also known as: Hot-Surface Ignition Temperature of Dust Layers
- Determines the lowest surface temperature capable of ignition a dust layer
- Used in conjunction with MAIT to define the maximum operating temperature for electrical and mechanical equipment

Other Tests to Consider

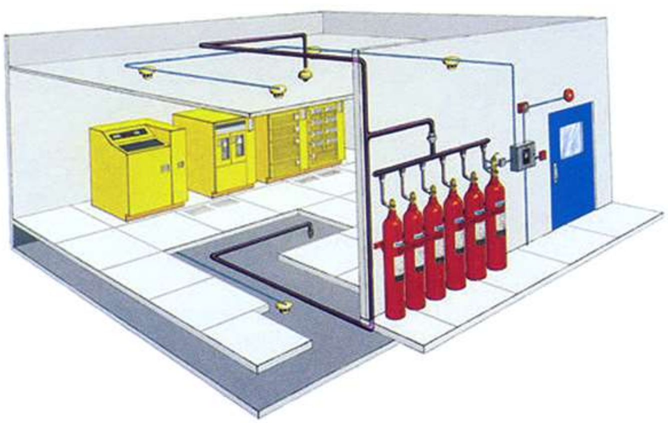
Limiting Oxygen Concertation, LOC (Vol % O2)

- Minimum concentration of oxygen capable of supporting combustion of a dust cloud
- Used for explosion prevention or severity reduction

Volume Resistivity (Ohm-m)

- A measure of the electrical resistance of a material to disperse an electrical charge
- Defines dusts as low, moderately or highly insulating
- Used in hazard assessment for evaluating electrical discharge potential

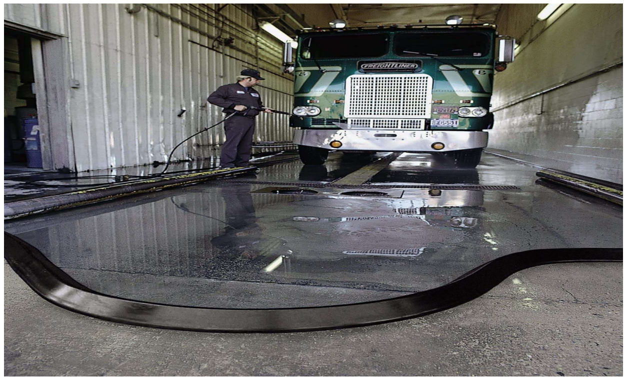
Fire protection and suppression system



Blow –out structures

Explosion venting on vessels

Spill containment



Prevention and protection measures

Housekeeping Procedures - Periodic

- Should be conducted at least daily and may be more frequently based on the process.
- At a minimum check for equipment malfunction or other upsets that result in unusual accumulations.
- Results must be documented
- If a process handling combustible particulate runs less frequently than daily, the inspections must take place at minimum daily when operated.

Housekeeping Procedures - Comprehensive

- Must be conducted periodically to inspect all areas in the facility for powder accumulations.
- Areas include elevated horizontal surfaces, I-beams, drop ceilings, hoist rails, ductwork and other hard to reach surfaces.

Methods of Cleaning

Vacuuming

- Preferred Method
- Vacuums must be rated for Class II (dust) hazard location
- Vacuum hoses shall be electrically conductive

Wet Methods

- Need to consider if electrical equipment can handle or need other means

Sweeping

- Need to have natural fiber brushes
- Vigorous dry sweeping is prohibited

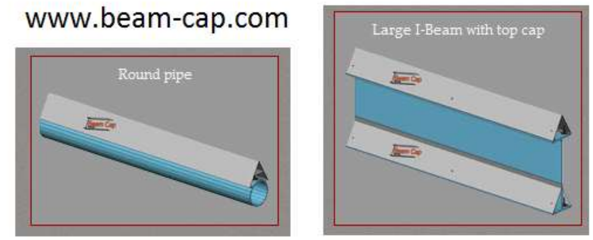
Compressed air

- Can only be use after vacuuming
- Limited to 30 psi

Facility design to minimize hazardous dust accumulations

- Local exhaust ventilation and central vacuum systems
- Minimize horizontal surfaces inside potentially dusty environments
- Use tubular steel instead of i-beams
- Sloped surfaces and round ductwork
- Contrasting color scheme to better see dust accumulation
- Seal off spaces that are difficult to be cleaned, but provide access for inspection

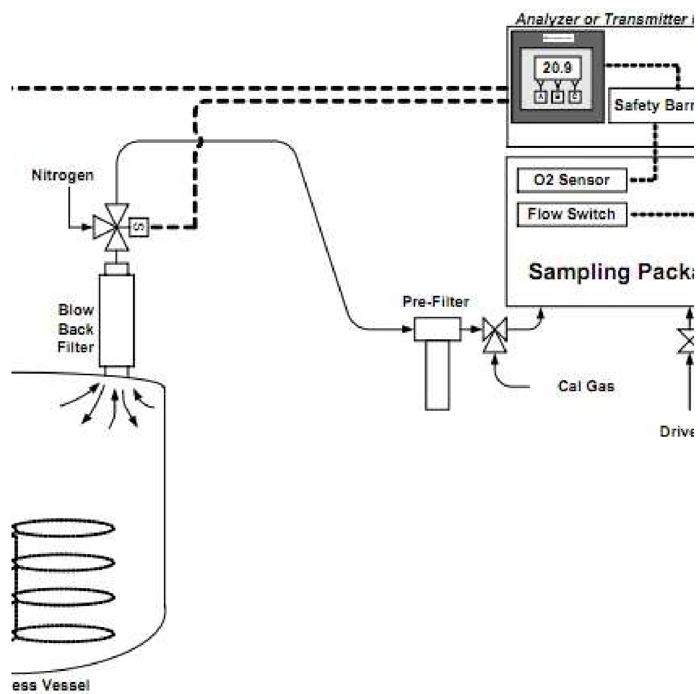
www.beam-cap.com



Prevention by inerting

- Reduce oxygen concentration below limiting oxygen concentration required for combustion
- Applied inside enclosed volumes
- Use nitrogen or carbon dioxide as inert gas to displace oxygen

- Typically, a control system in necessary for explosion prevention by inerting. A closed system is required for inerting, in which a control system would monitor the oxygen concertation and inject inert gas to keep the oxygen concentration well below the minimum oxygen concentration required for combustion. In lieu of a control system, a continuous inert gas supply could be used, if there is sufficient data to demonstrate the oxygen concertation will be maintained at a low enough level. Refer to Manual 80 A135 for Vessel Inerting requirements.



Explosion Venting

- Allowing the deflagration to by designing in a controlled failure point, usually a relief vent

- If indoors, the vent must be ducted outside

Explosion Suppression

Designed to detect and chemically suppress an explosion in its earliest stages - before an explosion can cause a disaster or become catastrophic

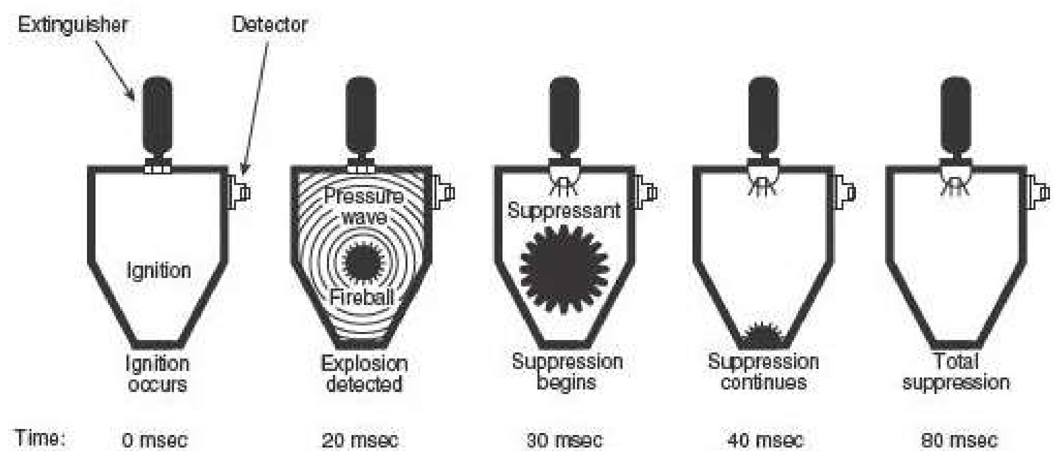


FIGURE B.5.1(a) Deflagration Suppression Sequence of Starch in a 35 ft^3 (1 m^3) Vessel.

Explosion Containment

Designed to contain the explosion within the equipment

Explosion Isolation

- For mitigation strategies that allow explosion to occur, isolation is paramount
  - Prevents explosion from spreading
  - Pressures increase in subsequent enclosures
  - Options for passive or active isolation

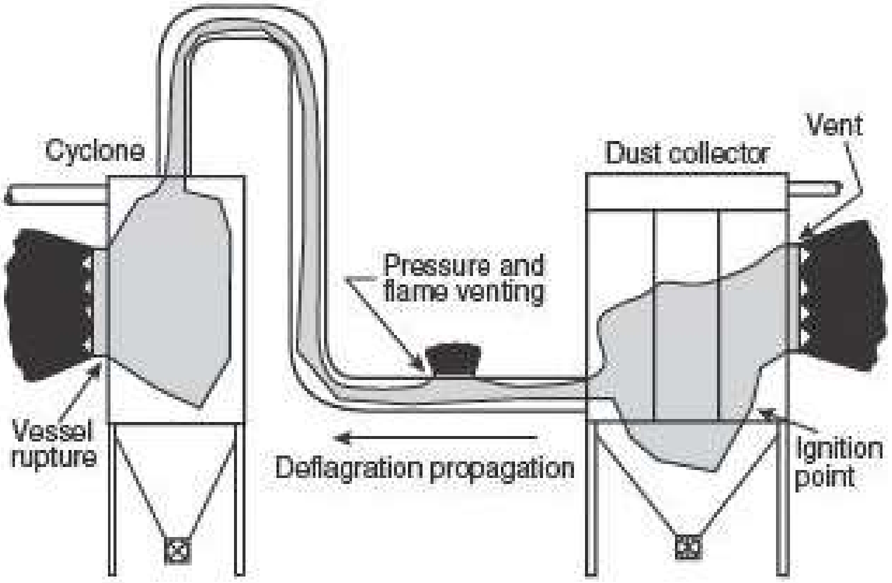


FIGURE E.1 Deflagration Propagation Without Isolation.

Explosion Venting Not Required for 8ft^3 (0.2m^3)

Why?

- Size is too small to apply explosion protection
- Need to understand the potential impact on the employees

Other Controls

- Bonding and grounding
- Housekeeping
- Training & Procedures

Fire Protection vs. Explosion Isolation / Suppression

PLEASE NOTE: fire protection & explosion isolation &/or explosion suppression are two different systems that need to be addressed independently.

- Explosion isolation &/or explosion suppression will **not stop a fire from occurring**, because these systems are activated via an increase in pressure.
- Fire protection is typically activated via an increase in **heat or presence of smoke**.
  - Most often, fire protection is supplied via sprinkler heads, or a CO2 system installed inside the housing/dirty side of the dust collector.
  - Certain types of combustible dust also require a spark detection system to be installed on the inlet duct of the collector, to spray water, etc. if a spark if detected in the duct, to prevent the spark from entering the dust collector housing (spark detection is required with wood dust).

* Please contact Facilities Engineering Fire Protection to define project requirements for your particular application.

Passive Explosion Isolation

Passive mechanical isolation devices are activated via the pressure wave generated during an explosion & prevent the flame front from traversing back into the process &/or occupied zone.

- A **Mechanical Flap Valve** is installed in the inlet duct of the collector. Backpressure cause the valve to close & remained closed, until inspected & manually reset
    - Inspection required monthly depending on manufacturer & requires dust collector to be shutdown
- **Pressure Relief Vent:** A pressure relief vent must be installed on the housing of the dust collector to relieve pressure & prevent the dust collector & ductwork back to the flap valve from breaking.
    - The pressure relief must vent to a safe location outdoors to a non-occupied area with no combustible materials within the flame front zone. An explosion will result in the vent panel to rupture, producing a flame front & pressure wave.
        - The size of the flame front & pressure wave can be calculated based on the dust properties & must be evaluated to assure the flame will not affect personnel or ignite nearby infrastructure.
- Inspection required annually & requires dust collector to be shutdown

Passive Explosion Isolation - Continued

- Flameless Vent
  - The flameless vent must vent to a non-occupied **area ~8'** radially. An explosion will result in the vent panel to rupture & the flameless vent will act as flame barrier. A pressure wave, heat & smoke may exit the vent.
  - Inspection is required annually per **NFPA 68** & requires dust collector to be shutdown
    - Manufacturer recommends quarterly inspection to assure the vent membrane has not been compromised, so that the flameless vent will function properly.
    - To avoid entering the dust collector (could require a confined space entry permit), the manufacturer recommends using a video camera on an extension stick to verify the vent connection has not been compromised due to erosion, etc.
  - IEP Manufacturer: The flameless vent connection to the dust collector housing is either a steel wool membrane or a steel membrane.
  - Fike Manufacturer: The flameless vent connection to the dust collector housing is a standard tin explosion vent.

Active Explosion Suppression

- Active explosion suppression systems monitor rapid pressure rise (beginning of an explosion) inside the dust collector housing, to activate chemical extinguishers mounted on the inlet duct & the housing of the dust collector.
    - Installing extinguishers on the outlet duct is optional
    - Imperial & Donaldson also offer filters that act as a flame barrier for the clean air / outlet air
- A non-toxic powder is released into the ductwork & dust collector housing, decreasing the oxygen concentration, which prevents further propagation of the explosion.
- **Chemical Suppression Companies**:
    - Fike (partnered with Imperial Dust Collectors)
        - If 3M wants to install a collector from a different manufacturer or retrofit a collector to add chemical suppression, a Fike C.S. system can be installed on anyone’s collector.
        - Fike chooses the chemical, but Sodium Bicarbonate is the most common.
    - IEP (partners with Donaldson):
        - If 3M wants to install a collector from a different manufacturer or retrofit a collector to add chemical suppression, an IEP C.S. system can be installed on anyone’s collector.
        - Sodium Bicarbonate is the only medium used in IEP’s extinguishers. It’s a food grade sodium bicarbonate that’s ground to a specific size to maximize effectiveness.

Isolation Between the Dust Collector Hopper & the Collection Container

- Rotary Air Lock:
  - Slowly rotate at a controlled speed, to allow material to drop out of the hopper, while not creating air disturbance in the hopper
  - The vanes of the air lock maintain contact with the sides of the valve opening, to prevent an explosion from propagating out the bottom of the collector
  - Motor required power & on/off controls
    - Must be turned off when changing the drum
  - Owner is responsible for inspecting (recommend monthly) the interior of the valve & the vanes to ensure erosion has not caused either to develop a gap & become ineffective
  - Verify dust rating of device (Kst & pressure)
    - Fike: rated for dust with a Kst ≤ 212 & Pred of
- Double Flap Dump Valve

MSIHC Rules 1989

Schedule – I, Flammable Chemicals

Flammable Gases : at 20 °C & 101.3 KPa are ignitable at ≥ 13 air volume or flammable range with air of at least 12 percentage points regardless of the lower flammable limits.

Extremely flammable liquids : Flash point ≥ 23°C & Boiling point > 35°C

Very highly flammable liquids : Flash point ≥ 23°C & Initial Boiling point < 35°C

Highly flammable liquids : Flash point between 23 to 60 °C

Flammable liquids : Flash point between 60 to 90 °C

Schedule – I, Explosives

Solid

Liquid

Pyrotechnic

Article

MSIHC Rules 1989

Industrial Activity	: An operation or process carried out in an industrial installation (Schedule 4) involving or likely to involve one or more hazardous chemicals and includes on-site storage or on-site transport which is associated with that operation or process, or isolated storage or pipeline. (schedule – 3)
Isolated Storage	: Isolated storage means storage of a hazardous chemical, other than storage associated with an installation on the same site (Schedule 4) where that storage involves at least the quantities of that chemical set out in Schedule 2. (schedule – 2)
Major Accident Hazards	: Isolated storage and industrial activity at a site handling (including transport through carrier or pipeline) of hazardous chemicals equal to or, in excess of the threshold quantities specified in Schedule 2 and 3.

On site and off-site emergency plant requirements.

Petroleum Rules 2002 (PESO)

Petroleum

: Petroleum means any liquid hydrocarbon or mixture of hydrocarbons, and any inflammable mixture (liquid, viscous or solid) containing any liquid hydrocarbon.

Class A	flash-point > 23°C	The total quantity in possession at anyone (1) place does **not exceed 30 L**.
Class B	flash-point ≥ 23°C to 65 °C	The total quantity in possession at anyone (1) place does not exceed 2,500 L and none of it is contained in a receptacle exceeding 1,000 L in capacity.
Class C	flash-point ≥ 65°C to 90 °C	The total quantity in possession at anyone (1) place does not exceed 45,000 L transported or stored.

Controlling and Licensing Authority : the Chief Controller of Explosives (CCE).
Notification of incident requires to be reported to CCE regional office.

Inflammable Substances Act 1952

What are dangerously inflammable substances?

As per the Inflammable Substances Act 1952, dangerously inflammable substance means any liquid or other substance declared to be dangerously inflammable. The liquids and other substances hereinafter mentioned are declared to be dangerously inflammable as per the Act,

- Acetone
- Calcium phosphide
- Carbide of calcium
- Cinematograph films having a nitro-cellulose base
- Ethyl alcohol
- Methyl alcohol
- wood naphtha

There are two primary hazards associated with flammable liquids: Explosion and Fire. In order to prevent these hazards, there is a primary concern of: **design and construction, ventilation, ignition sources, and storage**.

Gas Cylinder Rules 2016

"Gas Cylinder" or "Cylinder"

Any closed container having a **volume exceeding 500 ml** but **not exceeding 1000 liters** intended for the storage and transport of compressed gas, **including any liquefied petroleum gas (LPG) container or compressed natural gas (CNG) cylinder** fitted to a motor vehicle as its fuel tank but not including any other such container fitted to a special transport or under-carriage and includes a composite cylinder and cryogenic container, however, the water capacity of cylinder used for storage of CNG, nitrogen, compressed air, etc., may exceed 1000 liters up to 3000 liters provided the diameter of such cylinder **does not exceed 60 cm**.

Licensing : LPG ≥ 100 kg at any time or 25 cylinders **or** 200 kg of other flammable but non-toxic gas **or** 50 cylinders of acetylene

Requirement : Color coding of cylinder, Marking, Labeling, Storage, Valve specification hydraulic testing and rest of the rule's compliance assurance

The Static and Mobile Pressure Vessels (Unfired) Rules 2016

Pressure Vessels : Compressed gas, Capacity > 1000L with some expectations like water, steam, evaporator, heat exchanger, steam type digester, sterilizer, autoclave, reactors, clarifiers, pressure piping components such as separators or strainers and vessel containing a liquid under a blanket of compressed inert gas.

Requirements related to : Marking & painting, Pressure relief devices, Storage, Fire protection, Before transfer of gas, during transfer, on completion of transfer of gas, filling the vessel on vehicle etc.

Petroleum and Natural Gas Regulatory Board Regulation, 2020

- Regulating city and natural gas distribution network.
- Natural Gas pipe line
- Petroleum product pipelines
- Technical standard and specifications
- Gas exchange

Resources for the emergency management

Your best own onsite emergency plan

GHS/Hazmat labels

MSDS

Emergency Response Guide

Niosh Pocket Guide

Other guidance and references

OISD 179 : Safety Requirements on Compression, Storage, Handing & Refuelling of Natural Gas.

API 618 : Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services.

API 11P :High speed. oil & gas. compressors. (API 618 & API 11p). Reciprocating compressors.

NFPA 52 : CNG Vehicular Fuel Systems

NFPA 70 :The National Electrical Code (NEC), or NFPA 70, is a U.S. standard for the safe installation of electrical wiring and equipment

NFPA 37 :Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines

NZS 5425 :NZS 5425 Part 1 (1994): CNG Compressor and refueling stations

Static & Mobile Pressure Vessels (Unfired) Rules

ASME B31.8 : Gas Transmission and Distribution Piping Systems.

ASTM A 269 :Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

ANSI B 31.3 :Process Piping & Design of chemical and petroleum plants

ATEX :Design, examination and test of electrical and mechanical equipment, for explosive atmosphere

Gas cylinder rules :Design, manufacturing and handling of CNG cylinders

IS 7285:Specification for Seamless Steel Cylinders for Permanent and High Pressure Liquefiable Gases

Part I Refillable Seamless Steel Gas Cylinders – Specification for Normalized Steel Cylinders

EN 13 645 - Installations and equipment for Liquefied Natural Gas – Design of On-shore installations with a storage capacity between 5t and 200t

EN 1160 – Installation and equipment for Liquefied Natural Gas – General characteristics of liquefied natural gas

PED 2014/68/EU – Pressure Equipment Directive

EN 13 458 – Cryogenic vessels – Static vacuum insulated vessels

EN 13 480 – Metal piping systems

ATEX 2014/34/EU – Equipment and Protective systems intended for use in potentially explosive atmospheres (ATEX)

EN 60079-10 – Electrical apparatus for explosive gas atmospheres – Classification of hazardous areas

ISO 16924 - Natural gas fueling stations — LNG stations for fueling vehicles

ISO 16923 - Natural gas fueling stations — CNG stations for fueling vehicles

NFPA Standard to Reference in Design of Dust Collection Systems

- **NFPA 61**
  - Standard for Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities.
  - Prescribes specific controls relating to food industry, due to the large variety of combustible dusts and bulk material in food processing facilities. Such as grains, sugar, flour, feeds, and spices.
- **NFPA 68**
  - Standard for Explosion Protection by Deflagration Venting.
  - Contains design requirements and calculations for devices that vent pressures resulting from a deflagration in a dust collector.
  - Intended to minimize structural and mechanical damage to equipment if a deflagration even should happen.
- **NFPA 69**
  - Standard on Explosion Prevention Systems.
  - Prescribes the design of preventions controls for dust collection systems.
  - Prevention Controls include Isolation and Suppression devices.
- **NFPA 70**
  - Standard on National Electrical Code
  - Prescribes the design of safe installation of electrical wiring and equipment

NFPA Standard to Reference

- **NFPA 484**
  - Standard for Combustible Metals.
  - Outlines the procedures to determine whether a metal is in combustible form or not.
  - Prescribes specific controls relating to metal dust due to the severity of explosions and the relative ease of ignition.
  - Aluminum and Magnesium have specific requirements for dry dust collection.
- **NFPA 499**
  - Standard for Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
- **NFPA 652 & 654**
  - Standard on the Fundamentals of Combustible Dust & Standard for Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids.
  - General documents on how to design a safe dust collection system
  - Defines requirements for a Process Hazard Analysis and Risk Assessment.
  - Directs readers to many other relevant documents and more specific NFPA standards.
- **NFPA 664**
  - Standard for Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities.
  - Prescribes specific controls relating to wood dust, because of the tendency of wood processing equipment to create sparks and start fires.

NFPA Standard to Reference

NFPA 55 Compressed Gases and Cryogenic Fluids Code

NFPA 55 facilitates protection from physiological, over-pressurization, explosive, and flammability hazards associated with compressed gases and cryogenic fluids.

NFPA 58 Liquefied Petroleum Gas Code

The industry benchmark for safe LP-Gas storage, handling, transportation, and use, NFPA 58 mitigates risks and ensures safe installations, to prevent failures, leaks, and tampering that could lead to fires and explosions.

NFPA 30 – Flammable and Combustible Liquids Code

NFPA 34 – Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids

NFPA 70 – National Electrical Code

NFPA 497 Recommended Practice for the Classification of Flammable Liquids, Gases or Vapors and of Hazardous (Classified) Locations for

Electrical Installations in Chemical Process Areas

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

NFPA Standard to Reference

NFPA 30 – Flammable and Combustible Liquids Code

NFPA 34 – Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids

NFPA 70 – National Electrical Code

NFPA 497 Recommended Practice for the Classification of Flammable

Liquids, Gases or Vapors and of Hazardous (Classified) Locations for

Electrical Installations in Chemical Process Areas

NFPA 499 Recommended Practice for the Classification of Combustible

Dusts and of Hazardous (Classified) Locations for Electrical Installations in

Chemical Process Areas.

Hazardous area classification reference code

IEC 60079

IS 5571/72

NFPA 70/30/49/321

NFPA 30

Thank you