ATEX Establishing a Basis of Safety

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ATEX Establishing a Basis of Safety:

Section 1: Introduction

> "You cannot fall down stairs you don't have..."

Not our words ... but those of Trevor Kletz; renowned Guru in the field of process safety. What did he mean? Well, he was talking about 'bungalows' (single story buildings) and how they relate to **INHERENT SAFETY** – the very first topic which should spring to mind in any hazard or risk assessment i.e. how can we eliminate the hazard in the first place?

Later in the third section of this book, we look at the classification of hazardous areas and cite an incident in Mexico involving a water immiscible solvent (n-Hexane) which entered a town drainage system. Had the manufacturing process used a water-miscible solvent, many of those killed in the violent explosion would be alive today.

EU Areas and equipment in which combustible gases and/or vapours may form and in which airborne clouds may be produced, fall within the scope of the Dangerous Substances and Explosive Atmosphere Regulations 2002 Statutory Instrument No. 2776. A more detailed account of the principles involved is discussed in International Standard IEC 61241-19. The Regulation (Section 6.4 Risk Reduction) states the following measures, in order of priority, are those specified for risk control:

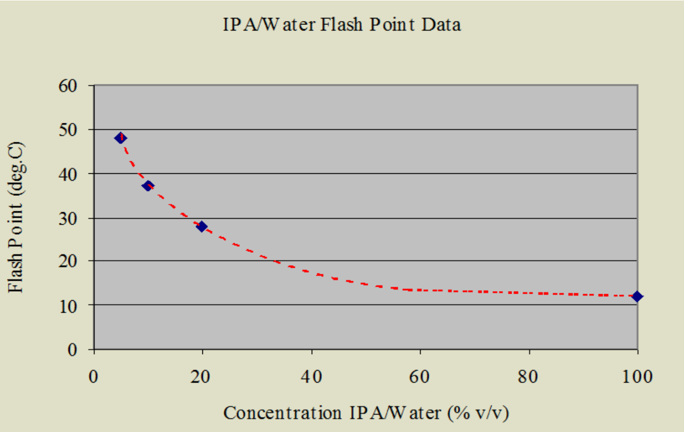
- **Reduction** of the quantity of dangerous substances to a minimum
- **Avoidance** or minimising the release of a dangerous substance
- **Control** of the release of a dangerous substance at source
- **Prevention** of the formation of an explosive atmosphere, including the application of appropriate ventilation
- **Ensuring** that any release of a dangerous substance which may give rise to risk is suitably collected, safely contained, removed to a safe place, or otherwise rendered safe, as appropriate
- **Avoidance** of ignition sources including electrostatic discharges and adverse conditions which could cause dangerous substances to give rise to harmful physical effects
- **Segregation** of incompatible dangerous substances

Dilution

Simple steps, for example, could help eliminate the hazard – like adding water to an alcohol or changing the process operation e.g. method of addition.

Pure iso-Propyl Alcohol (IPA) will form flammable atmospheres in air under ambient conditions because it has a low flash point value i.e. 12 °C.

Hence, hazardous areas will arise during handling and inside process vessels under normal ambient temperature conditions. But could an IPA-water mixture be used in place of the pure solvent?



Dilution with water results in an increase in the closed-cup flash point value. This arises because the rate of evaporation is suppressed. The graph shows empirical data from which a 'line-of-best-fit' relationship has been determined:

$$y = 106.7 x-0.4674$$

where:

y = flash point (°C), and
x = IPA concentration (% v/v)

Ref: http://www.nugentec.com/FAQ/Fr...

With a 5K safety margin, if the temperature of an IPA/H2O solution can be restricted to normal room temperature (say 25 °C) or below, hazardous vapour-air mixtures can be avoided by controlling the alcohol content to 15 % IPA by volume or less (equivalent Flash Point = 30 °C). Clearly, lower concentrations provide an even greater margin of safety.

Change in Procedure

When pouring liquids with moderate flash points (e.g. Flavours) in to a heated batch, to preclude the formation of hazardous areas within the vessel, some liquids (Flavours) have to be restricted, dependent on their flash point. To eliminate this, one option is to dilute the flavours with some of the batch liquor in a separate area (i.e. within a ventilated cubicle or fume cupboard), prior to the addition of the (then) diluted mixture.

Occasionally, to achieve the same goal, the batch temperature can be lowered, although this is not always a tenable solution. Increased ventilation offers a third alternative, whereby extraction (LEV) is provided immediately above the point of addition i.e. rather than at (say) ceiling level.

Ventilation

With increased ventilation, the extent of the hazardous area will be reduced. Suitable ventilation rates can also avoid persistence of the explosive atmosphere, thus influencing the type (and/or extent) of a zone. However, key points need to be considered in the use of ventilation:-

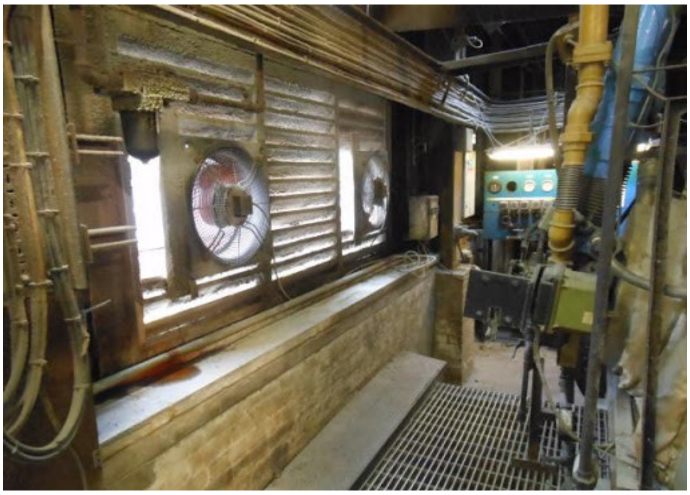
- Effectiveness should be controlled and monitored
- Extract discharge point requires consideration
- Air should be drawn from a non-hazardous area
- Release conditions must be defined
- Need to consider changes in gas densities (with temperature)
- Need to consider flow of heavier-than-air gases
- Need to consider local obstacles/impediments to air movement

Ventilation is often categorised as follows:

High ventilation (VH) – can reduce the concentration at source virtually instantaneously, resulting in a concentration below the LEL. A zone of small (or even negligible) extent results.

Medium ventilation (VM) – can control concentration, resulting in a stable situation where the concentration beyond the zone boundary is below the LEL whilst the release is in progress and where the hazardous area does not persist unduly, after the release stops.

Low ventilation (VL) – cannot control the concentration whilst release is in progress or prevent undue persistence of hazardous area after release has stopped.



Need to consider local obstacles/impediments to air movement.

Hazardous Area Classification

The process of area classification involves the identification of all flammable materials, the identification and grading of all releases of flammable material, the assessment of the level of ventilation and/or housekeeping and the determination of the resulting types and extents of the zones. In turn, the designation of zones enables the correct equipment, practices and procedures to be applied to protect the health and safety of the workers concerned with the facility.

It is important to note that area classification only deals with reasonably foreseeable events and does not consider highly improbable ('catastrophic') events. EN 60079-10 section 1.1(d) defines 'catastrophic' failures as 'beyond the concept of abnormality dealt with in the standard' and lists 'the rupture of a process vessel or pipeline and events that are not predictable' as examples.

Thus, a 'catastrophic' failure may cause an explosive atmosphere to be present in an area defined by area classification as 'non-hazardous' and such situations are subject to a risk assessment by the operator under other legislation.

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Quick-fix ‘Gaffer Tape’, often used for a temporary repair, is not a sound engineering solution. Moreover, in many cases, it becomes a permanent fixture! Certainly not an example of catastrophic failure.

Warehousing is not immune to risk either! A recent audit found several contraventions of HSE Guidelines:

- Storage of flammable liquids within the confines of the building
- Shared storage of oxidising materials and flammable liquids in the building
- No provision of natural or forced (mechanical) ventilation (battery charging)
- Processing (mixing) operations undertaken within a warehousing environment
- Limited segregation of operations
- An opportunity for the release of gaseous oxidants within the building

Simple procedures can help hugely; such as protecting containers against banging or other physical damage when storing, transferring or using them and not using wooden pallets or other combustible pallets for storing containers of oxidizing materials and of course, ensure containers are suitably labelled.

In 2004, ICL was fined £400,000 over a factory explosion at Stockline Plastics in Maryhill, Glasgow.

The blast killed nine workers and injured 40 others and was Scotland's worst industrial disaster since the Piper Alpha oil rig explosion and fire in 1988.

The blast was caused by a build-up of liquid petroleum gas that had leaked from pipes. The pipes dated back to 1969 and were so badly corroded that escaped gas was ignited when a builder flicked a switch in the factory.

The High Court in Scotland was told that the pipework in question would only have cost £405 to replace and that one risk assessment undertaken was carried out by a college student doing vacation work.

Stockline Plastics Factory Explosion

Section 2: Characterising Your Material Hazards

Industries producing and/or handling materials which may form hazardous (flammable) atmospheres must comply with the ATEX Directives.

In the UK, this requires compliance with the Dangerous Substances & Explosive Atmospheres Regulations (DSEAR). Similar NFPA Codes apply In the USA.

You cannot define the necessary systematic approach to protecting people and plant, without a knowledge of the potential hazards in your work place - are flammable atmospheres present within your plant or processing areas?

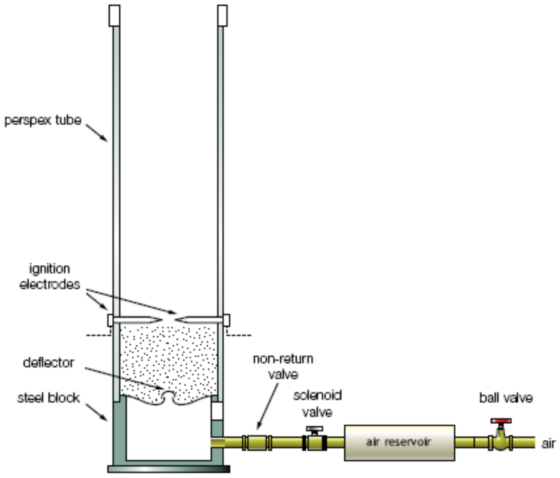
The first step is to check your suppliers' MSDS's, your own records and the open literature for relevant test data.

Gestis is an EU funded database of combustion and explosion characteristics of more than 6000 dust samples from virtually all sectors of industry to help establish a basis of safety for the safe handling of combustible dusts. Gestis data is generic and may be indicative only e.g. it may not cover specific formulations or compounds, in which case, testing will be required.

> *Where a dangerous substance is or is liable to be present at the workplace, the employer shall make a suitable and sufficient assessment of the risks to his employees which arise from that substance.*
>
> \- Gestis

How do you know a material is dangerous unless you test it?

Group A/B (Vertical Tube) Test: Essentially, the dust under test is dispersed in air at ambient temperatures, past a source of ignition and observations of flame propagation made by the operative. The photograph shows the test apparatus with the tube removed for clarity. This classification test is a qualitative assessment of the ability of a dust to take part in an explosion:



- Group A is a dust, which is able to ignite and propagate flame.
- Group B is a dust, which does not propagate flame.

As in all explosion testing, the sample selected must be representative of the material from the plant at risk, typically the finest and driest material found.

Further testing is required for Group B samples if handled at elevated temperatures >110 degree C. Although this test may be superseded by the 20-litre sphere, it does give a very good visual feel for how the dust reacts to an ignition source at ambient temperature.

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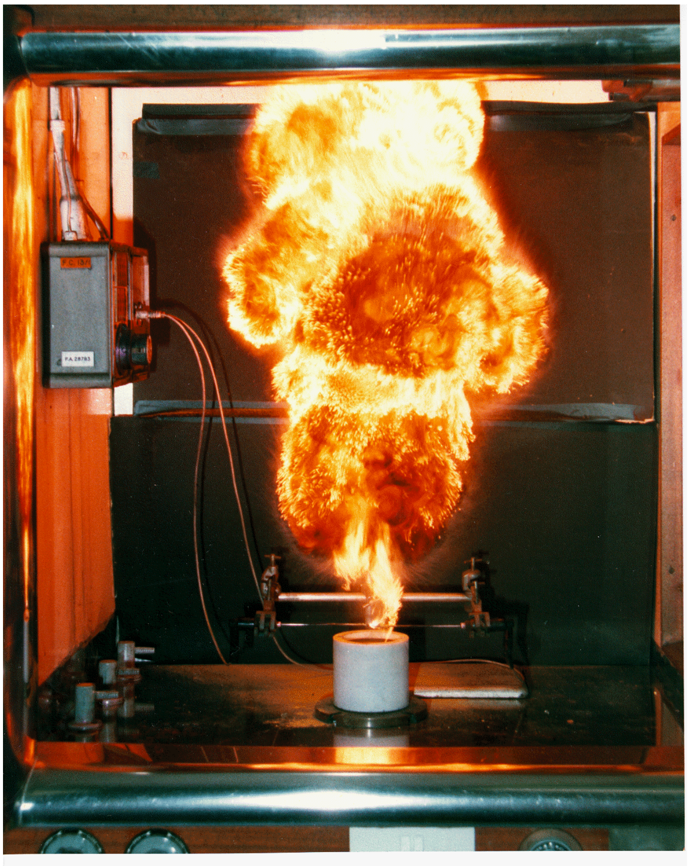
Once you have established that the dust is Group A Explosible, the next step is to examine the specific ignition and explosion parameters.



Dust Concentration

Lower Explosion Level (LEL for gases and vapours) or Minimum Explosible Concentration (MEC for powders) is typically of the order 45g/m3 and 30-60 g/m3 respectively. The Upper Explosion Level (UEL) not as clearly defined for powders, but usually is >1000g/m3.

Do you leave footprints where you walk?

If so, there may be a secondary explosion risk.

Consider a room 10 m x 10 m x 5 m high. What thickness of deposits will form a flammable (explosible) atmosphere throughout the room?

A thickness of just 1 mm can equate to 75 kg of powder (depending on density) and if this was dispersed in the 500 m3 volume, the resulting concentration is 75,000 / 500 = 150 g/m3 i.e. well within the flammable range.

How might this be dispersed, you may ask? During cleaning operations using air-jetting!

Particle Size

This is a very important factor as particles greater than 500micron are unlikely to cause dust explosion hazards.

This is why most tests are carried out below 100 micron or the standardised 63 micron. This may be a futile action due to attrition, as transportation of granular material may create a fines fraction.

Moisture Effects

Explosion violence falls at higher moisture contents:

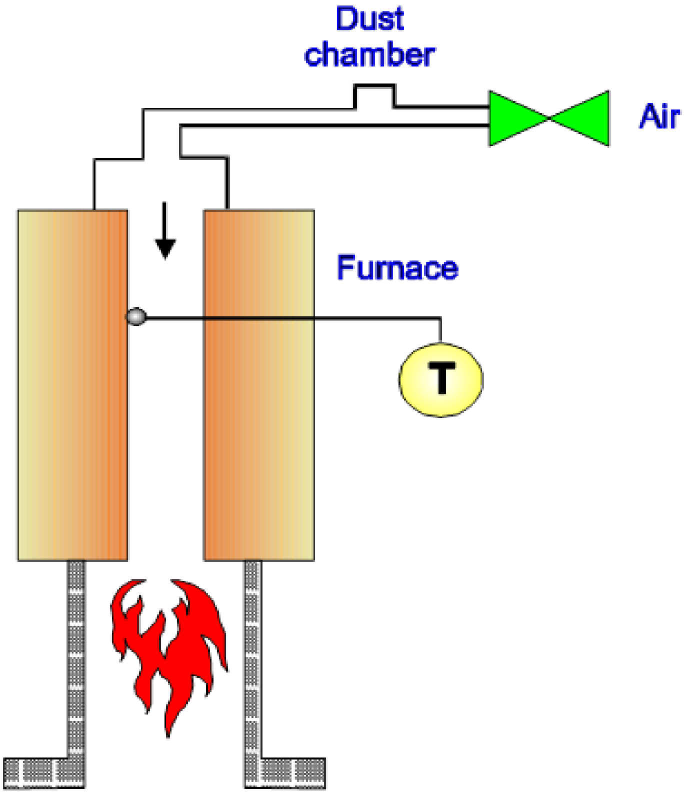
- 0-5% has little effect
- 5-10% decreases sensitivity
- >25% particles unlikely to stay in suspension

Minimum Ignition Temperature: MIT Cloud

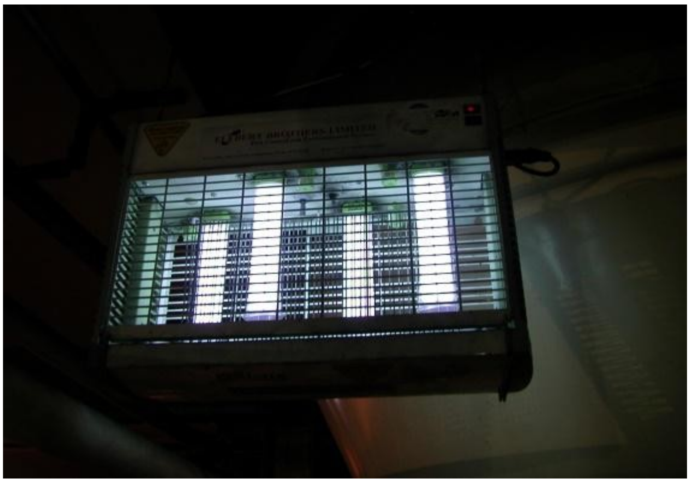
The Minimum Ignition Temperature of a dust suspension is the lowest temperature at which it will ignite spontaneously and propagate flame.

This MIT value is particularly relevant to problems involving relatively large heated areas of plant e.g. surfaces of dryers, mills, electrical equipment, etc.

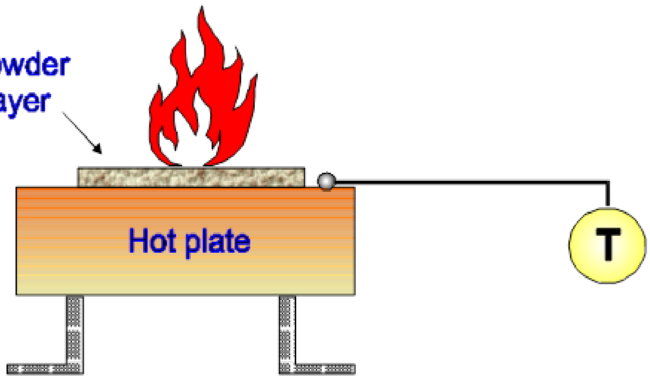
For example, you need to ensure that any escape of dust (as a cloud) does not spontaneously ignite on nearby heated surfaces e.g. electrical motors, insect-o-cuters, etc.



Ancillary equipment such as this is often ‘missed’ (overlooked) when shutting down plant for cleaning and maintenance purposes.

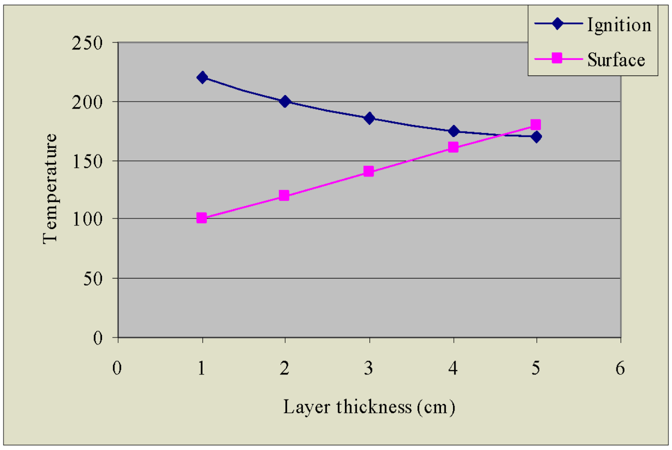


Minimum Ignition Temperature: MIT (LIT) 5 mm Layer



The test determines the minimum temperature of a prescribed hot surface, which will result in the decomposition and/or ignition of a layer of powder of specified thickness. The test is particularly relevant to industrial equipment with hot surfaces, on which dust deposits may form.

For example, you need to ensure that any escape of dust (which forms a layer) does not result in smouldering. Equipment must be kept clean with surface layers not exceeding 5 mm. Thicker layers will invalidate the T rating of equipment and may cause ignition.



Minimum Ignition Energy: The Dust Cloud

Minimum Ignition Energy of a dust suspension is the lowest energy at which ignition and flame propagation away from the spark kernel occurs - the value being particularly relevant to identifying potential electrostatic ignition hazards. In principle, the test is similar to the Group A/B Test.

Two circuits are employed – capacitive (for electrostatic ignition) and inductive (for friction spark ignition). Essentially, the difference between them lies in the duration of the spark i.e. increasing inductance will lengthen the duration of the discharge making it more incendive.

Consequently, the MIE value with this circuit will be lower than that with a capacitated circuit e.g. 10 mJ compared to 30 mJ. Typically, MIEcap values range from 3 – 1000 mJ for dusts and 0.017 – 0.4 mJ for gases and vapours.

Minimum Oxygen for Combustion / Limiting Oxygen Concentration (MOC / LOC):

Essentially, a flammable atmosphere (be it gas, vapour or airborne dust) cannot exist below this level of depleted oxygen. The data is needed when basing safety on the use of inert gas, in certain milling or solvent handling operations, for example. The test is conducted in a 20 Litre Explosion Sphere.

Typical MOC values lie in the range 8 – 15 % v/v (for powders) and 5 – 10 % v/v for gases and vapours. It is important to note that the MOC value depends on the type of material and the type of inert gas.

The following schematic shows the flammable envelope for Methane.

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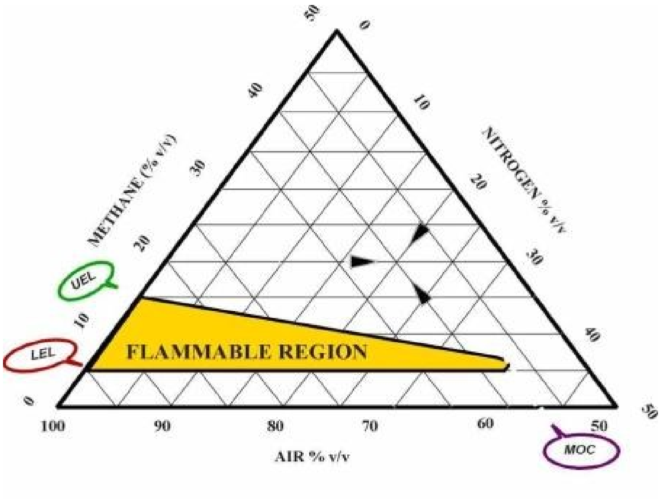


Figure 1. Flammable Envelope for Methane

Explosion Characteristics: Kst & Pmax

Although the methods above are relevant for prevention of flame and explosions, to confirm the quantitative assessment of a design for explosion protection you will need to conduct an actual controlled dust explosion in either the 20 litre or 1m3 test apparatus.

The dust sample is homogenously dispersed via deflector plates (typically) and ignited by a 10kJ source.

The development of the explosion pressure with time is monitored and the maximum peak pressure Pmax and maximum rate of pressure rise is obtained after a testing over a range of dust concentrations.

The peak value of the maximum rate of pressure rise (dp/dt) max is used to calculate a dust specific explosibility characteristic called Kst or Kmax = dp/dt max. V1/3.

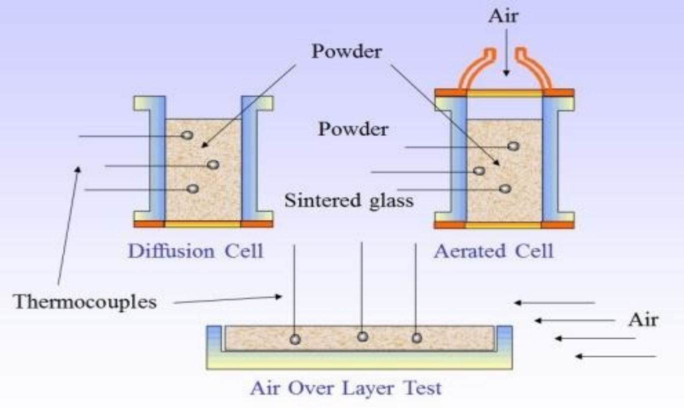
Material	P max	Kst bar m/s
Methane	8.4	58
Hydrogen	8.2	503
Sugar	8.0	80
Coal	7.7	85
Starch	9.4	150
Cellulose	10.0	160
Milk Powder	8.2	147
Dextrin	8.7	200
Aluminium	11.5	555

As shown, dust explosion pressures can reach the same as gases/vapours and some metal dusts can be as dangerous as Hydrogen.

Thermal Instability Testing

The Diffusion Cell, Aerated Cell and Layer Tests are used to assess the thermal stability of a material in bulk or layer form e.g. inside Dryers, etc.

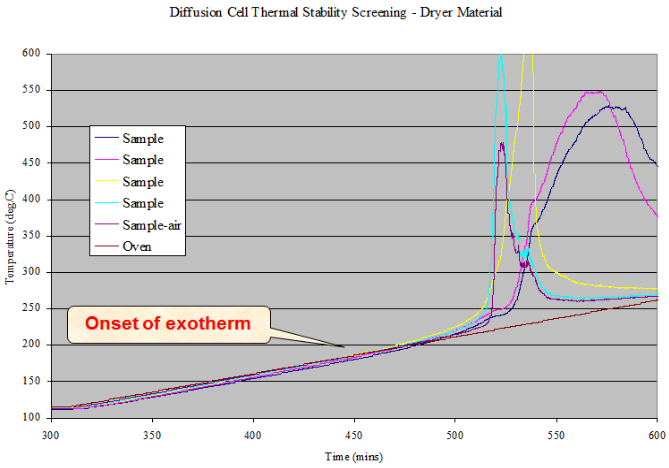
The cells are located in fan assisted ovens which can be run isothermally or in ramped mode. In addition, large scale basket tests may be required to assess the effect of scale.



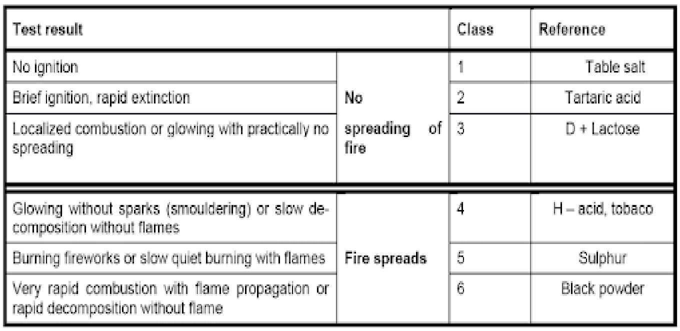
Description of Burning and the Corresponding Classes

A separate Combustibility Test (comprising a train of powder ≈ 200mm long, ≈ 30mm wide and ≈ 20mm high) is used to assess the type and rate of flame/smoulder propagation along a layer of material e.g. inside ductwork, etc.

It can also be used as an indicator of UN. Div. 4.1 'Flammable Solid' material for transport purposes.



Diffusion Cell Thermal Stability Screening - Dryer Method



Test result		Class	Reference
No ignition	No spreading of fire	1	Table salt
Brief ignition, rapid extinction		2	Tartaric acid
Localized combustion or glowing with practically no spreading		3	D + Lactose
Glowing without sparks (smouldering) or slow decomposition without flames	Fire spreads	4	H – acid, tobaco
Burning fireworks or slow quiet burning with flames		5	Sulphur
Very rapid combustion with flame propagation or rapid decomposition without flame		6	Black powder

Table 1 — Descriptions of Burning and the Corresponding Classes

Section 3: Hazardous Area Classification

The dangers of siting electrical apparatus in areas where explosive mixtures of gases and air could occur were first recognised in the mining industry early in the 20th Century.

The chemical and petrochemical industries recognised that, unlike coalmining, the occurrence of flammable atmospheres was due to mechanical and process failures or deliberate situations created by man.

This newspaper article covers a widespread n-Hexane vapour explosion through a drainage system, although reporters referred to is as a 'gas' explosion.

10 INTERNATIONAL THE INDEPENDENT

Mexican gas disaster may have killed 1,

From Jeff Silverstein
in Guadalajara

RESCUE workers and sniffer dogs continued their search for more victims from Wednesday's deadly gas explosion as an eerie calm descended on the streets of Guadalajara yesterday.

Reports on the casualties varied greatly, but Mexican Red Cross officials had put the number of dead at more than 200 by yesterday morning, mainly women and children, and said there could be as many as 1,000. According to some rescue workers on the scene, 86 more victims had already been found early yesterday.

"It's impossible to know how many more dead bodies are going to be pulled out of the rubble," said Gabriela Fernandez, an army medic, standing in a debris-strewn side street.

Thousands more were injured when the Reforma district of the city was rocked by a series of at least 20 explosions, bringing down one- and two-storey buildings and small shops in a 30-block area. The hardest-hit area was Calle Gante, a street close to the city's historic centre. Almost 20 blocks were reduced to rubble, apparently when hexane gas trapped in a sewer ignited, sending cars flying into the air and carving a 20ft crater the length of the street.

Bodies have been taken to a sports stadium and local hospitals for identification by relatives, and the governor of the state of Jalisco, Guillermo Cosio Vidaurri, has ordered the state university to be opened to provide emergency housing for victims.

Police, Red Cross and volunteer rescue workers are still holding out hope, however, that they will find survivors. No heavy equipment is being used in the rescue operation. Instead, rescue workers are carefully removing the debris piece by piece.

At a meeting at City Hall yesterday morning, local officials warned that there was still a danger of more explosions. The smell of gas continued to linger in the air. In some parts of the city the odour was so strong that rescue efforts had to be put off, and many bodies could still buried there.

More than 80,000 people are said to be without water, and the government fears that diseases may soon begin to spread. Around 50 plastic tanks holding up to 10,000 litres of water have been moved into the disaster area and a vaccination programme is expected to begin today .

The cause of the explosion, meanwhile, still remained a mystery yesterday, and people were demanding to know how the tragedy was allowed to happen. Local officials say that hexane gas, a hydrocarbon used as a solvent in food processing, was mistakenly leaked into the sewerage system's storm drains.

Eduardo Mestre, of the National Water Commission, said that the city's sewerage system is inadequate. Industries are not obliged to instal their own waste disposal systems, so dangerous substances can find their way into the main drains. The law on this is about to be changed, but it has come too late for Guadalajara.

Officials of the state-owned oil company, Pemex, are also being investigated. But some people have already expressed fears that any inquiry will be kept secret and Wednesday's gas explosions are a prelude to other accidents waiting to happen unless industrial safety standards are enforced.

"There has been a history of cover-ups when the Mexican government has been involved in investigations in the past," said Homero Aridjis, a prominent environmentalist. Pemex has been involved in several past explosions in Mexico, including three during the 1980s. In 1984, a gas explosion in San Juan Ixhuatepec just outside Mexico City, killed more than 500 people and forced the evacuation of 200,000.

Pemex has issued a statement, however, saying that the source of the gas leak was a privately-owned cooking oil factory, La Central.

According to local residents, gas could be detected in the air as early as Tuesday morning. That same night, firemen were sent to the area, where they stayed until the early hours of the next morning, but decided not to evacuate the area. Hours later, a series of explosions with the force of a powerful earthquake was to rock the neighbourhood.

President Carlos Salinas de Gortari, who arrived in the city on Wednesday night, has ordered the Attorney-General to lead an inquiry and bring criminal charges if necessary. His appeal for international help has so far been answered by Britain, the United States, Cuba and France.

A girl walks away from the rubble of a building after gas explosions devastated part of Guadalajara. Rescue workers still hope to find survivors

Fujimori defies critics with 'reform' package

By Colin Harding
Latin America Editor

WHILE opposition leaders and the United States government rejected President Alberto Fujimori's undertaking to return Peru to democratic rule within a year, the President moved to shore up his domestic position with a mass rally in Lima's main square on Wednesday night. Mr Fujimori

mains worthy of debt restructuring aid and investment while the necessary political surgery is being performed. The success of the economic stabilisation and liberal-

austerity has been raised by the resignation of the Economy Minister, Carlos Boloña, and the impending dismissal of the president of the Central Bank, Jorge Chavez. Mr Boloña was the architect of the current free-market model, and he is said to have made his

Earthquake jangles nerves in Califo

From Matt Spetalnick
of Reuters

LOS ANGELES – A powerful earthquake whose shockwaves were felt from the skyscrapers of Los Angeles to the towns of the high desert raised fears yesterday that the long-awaited "Big One" is on the way.

Hundreds of aftershocks continued rumbling through the area after Wednesday night's quake rattled the sparsely populated communities east of Los Angeles. Dozens of structures were damaged, gas lines snapped, power was knocked out and goods were shaken from store shelves.

The quake registered 6.1 on the Richter scale – a magnitude capable of causing se-

damage, mostly in small desert towns. At least 20 people were reported injured.

When it struck at 9:51pm Pacific time (0451 GMT yesterday), high-rise buildings swayed in Los Angeles, cars bounced on the busy highways and the ground shook as far away as Las Vegas, Nevada.

Seismologists said there was still a 5 per cent chance that it could be followed within three days by a potentially devastating 7.5

quake that battered the San Francisco area during the 1989 baseball World Series – but that the threat, at one point as high as 25 per cent, was diminishing as time passed.

"If we get through the day without a bigger-size quake, we will all be more relaxed," said seismologist Egill Hauksson of the California Institute of Technology.

Police and fire departments were on full alert in six southern California counties yesterday as authorities worked to remove fallen power lines and restore phone service to remote areas hardest hit by the quake.

The quake and its aftershocks jangled the

Hazardous Zones

A fairly simple set of rules was developed dividing areas where flammable atmospheres could occur into 3 areas of risk, based upon frequency and persistence.

This approach was taken up nationally and appeared in a British Standard Code in 1959.

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Today hazardous area classification (HAC) covering natural gas installations, solvent handling, oil pumping, etc. is a statutory requirement throughout EU Member States and under the Dangerous Substances & Explosive Atmosphere Regulations 2002 (in the UK), in particular.

The zone definitions are as follows:-

Zone 0

A place in which an explosive atmosphere (from gas, vapour, mist or spray) is present **continuously or for long periods or frequently** – e.g. solvent storage tank operating continuously above the flash point of the liquid, etc.

Zone 1

A place in which an explosive atmosphere (from gas, vapour, mist or spray) is likely to occur ***in normal operation occasionally*** – e.g. sampling point where the liquid is above its flash point temperature, etc.

Zone 2

A place in which an explosive atmosphere (from gas, vapour, mist or spray) is not likely to occur **in normal operation** but, if it does occur, will persist for a short period only – e.g. leakage from gas pipework flanges, fittings, etc.

Key parameters to be considered include liquid flash point, gas or vapour density, the leak or emission rate, the prevailing level of ventilation (natural or forced), pressure, temperature, LEL, height of release, etc.

Oddly, historically, the HAC job was often given to electrical or instrument personnel when it was (and still is) a matter for process engineering!

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Zone 20

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present **continuously or for long periods or frequently** – e.g. inside cyclones, hoppers, containers, pipework, etc.

Zone 21

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur **in normal operation occasionally** – e.g. vicinity of powder filling/discharge points, weigh stations, sampling points, etc. and where dust layers occur and are likely in normal operation to give rise to an explosive concentration.

Zone 22

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is **not likely to occur in normal operation** but, if it does occur, will persist for a short period only – e.g. outlets from cyclones, clean-side of dust filters, etc.

Gas Installations

Historically, the following probability values have been used for guidance (with gases/vapours) and these are commonly applied to solids handling also.

Continuous source	(> 1000 hrs.yr-1) yields a Zone 0 / 20
Primary source	(10 - 1000 hrs.yr-1) yields a Zone 1 / 21
Secondary source	(<10 hrs.yr-1) yields a Zone 2 / 22

The relevant code of practice for **Gas Installations** with working pressures up to 2.0 bar.g is IGEM/UP/16 Comm. 1756

> *'The design of natural gas installations on industrial and commercial premises with respect to hazardous area classification and preparation of risk assessments'.*
>
> — *UK Dangerous Substances & Explosive Atmosphere Regulations 2002*

Essentially, the use of effective and appropriate ventilation is the key to precluding hazardous areas in Boiler Houses, battery charging areas, etc. other than Zone 2 (NE) i.e. of negligible extent.

Flammable vapour atmospheres will arise when liquids are handled or processed above their flash point temperature.

A 5K safety margin is normally applied for pure materials (solvents) when using flash point temperatures to define whether or not flammable vapour-air mixtures will be formed. A larger 15K safety factor is recommended, however, for liquid/liquid or liquid/solid mixtures. For spillages, the open cup flash point (rather than close cup) value is more appropriate.

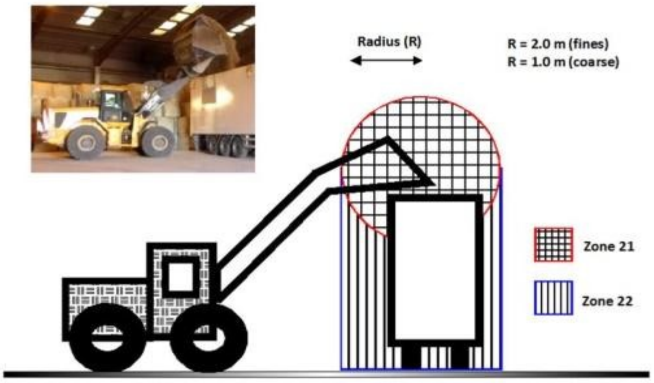
The above discussion relates vapour pressure to temperature and in essence, assumes 'saturated vapour-liquid equilibrium'. Care is needed with operations which produce high shear forces on a fluid, resulting in 'non-equilibrium' conditions e.g. high speed mixing, splash loading, etc.

Similarly, flammable atmospheres can arise through mist or spray formation (by mechanical means or condensation). Fine mists can form flammable mixtures well below (may be 200K or more) the flash point of the liquid. The potential hazard arises from leakage of fluids under pressure, from compressions joints, oil seals, etc. The use of flange-guards can eliminate the hazard, however.

Dust

In the case of dusts, most sources of release in normal operation should be small, and should be controlled at source, since the increasing concern to reduce occupational health risks from breathing in airborne material should have reduced the number of areas where dust is released regularly into the general atmosphere.

With regard to the extent of a hazardous area (Zone), this very much depends on how much dust is released and whether it would be released as a heap that settled quickly on the floor or as a large cloud. For instance, a sack that tore as someone picked it up might release (say) 5-10 kg, but most would settle very quickly. However, a Flexible Big-Bag (FIBC) where the tie became loose after lifting might release 500 kg (or more) at high level. Also, a pneumatic transfer line might release a very large amount as a cloud.



Unlike releases involving gases and vapours, there is no simple method available of calculating how far from the source a release of dust of a given quantity with a known pressure behind it will form a dense cloud.

However, it is clear that if the release could produce a dense cloud (say larger than a couple of metres from the source), a means of minimising quantity of dust that could be released and its spread should be sought. Often, the provision of simple plastic or fabric curtains are considered to be helpful.

Predictable Hazardous Areas

Equipment which is opened up for cleaning, maintenance, etc. may give rise to explosible dust clouds externally if material held-up on internal ledges, back-sides of doors, etc. is dislodged.

To cover this, a 'generic' Zone 22 area of 1.0 m extent (to solid floor level) is often proposed.

However, since the formation of such hazardous areas is predictable, it is not necessary to provide certified equipment within the hazardous area so formed if the work is done under a STRICT permit system i.e. a safeguard whereby uncertified (unsuitable) equipment within the vicinity has been de-energised and isolated. The hazardous area still remains, however.

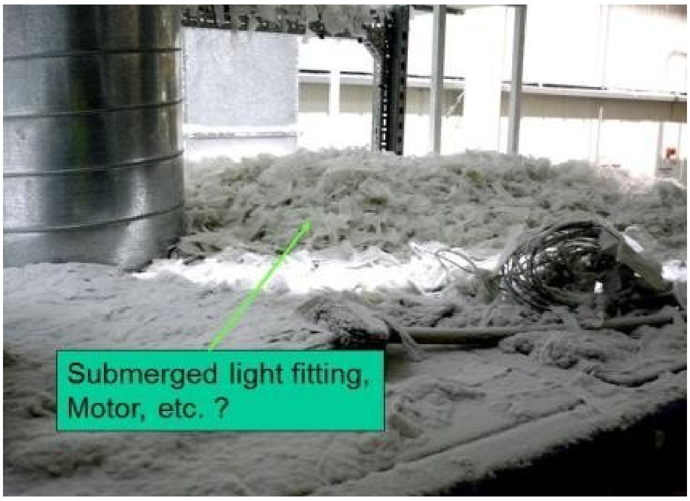
Dust Extraction

Dust extraction is important to limit fugitive emissions and it should be routinely monitored to ensure satisfactory performance. In addition, the level of ventilation should ensure that the dust-air concentration does not routinely exceed 25 % of the lower explosive limit LEL or minimum explosible concentration MEC).

The 'capture velocity' is also important and this depends on the level of air movement in the region of interest.

Release type	**Capture velocity**
Still air / low momentum	0.5 – 1.0 m.s-1
Moving air / particles	1.0 – 2.5 m.s-1
Turbulent / high momentum	2.5 – 10 m.s-1

Dusts, which are not removed by mechanical extraction ventilation, settle out, at a rate depending on properties such as particle size, into layers or accumulations and account has to be taken of the fact that dilute or small continuous sources of release (in time) may produce a potentially hazardous dust layer.



Principally, three risks are presented by dust layers:

Risk 1: A primary explosion within a building may raise dust layers into clouds, and cause secondary explosions more damaging than the primary event. Dust layers should always be controlled to reduce this risk.

Risk 2: Dust layers may be ignited by the heat flux from equipment on which the layer rests. The risk is of fire, rather than explosion, and this may be a slow process.

Risk 3: A dust layer may be raised into a cloud, ignite on a hot surface and cause an explosion. In practice, dust cloud ignition temperatures are often much higher than layer ignition temperatures. For example, Paper fines have a layer ignition temperature of 210 - 275 °C, but a cloud ignition temperature of > 450°C.

These risks depend on the properties of the dust and the thickness of layers, which is influenced by the nature of the housekeeping. The likelihood of a layer catching fire should be controlled by the correct selection of equipment and effective housekeeping.

Signage

Arrangements must be made for the display of 'EX' signage in appropriate locations. Additional information (wording) can be incorporated to highlight the specific hazard i.e. Explosive Gas/Vapour/Mist Hazard or Explosible Dust Hazard

Section 4: Potential Sources of Ignition

EU **'ATmosphere EXplosif'** (ATEX) Directives require manufacturers to provide safe (certified) equipment for use in hazardous areas under the Equipment Directive previously referred to as ATEX 95 now 114.

Similarly, users of equipment are required to assess both the likelihood of forming a hazardous area and the risks from ignition (identification and control) under the Use Directive previously referred to as ATEX 137 now 153.

ATEX Establishing a Basis of Safety

Standard BS EN 1127-1:2011

'Explosive Atmospheres – Explosion Prevention and Protection Part 1. Basic concepts and methodology' distinguishes between 13 types of ignition source:

Common	Less Common
Mechanically generated sparks	Stray currents & cathodic protection
Hot surfaces (e.g. binding friction)	Electromagnetic fields (9 - 300 GHz)
Flames and hot gases	Electromagnetic radiation (3 x 1011 to 3 x 1015 Hz or wavelength range from 1000 μm to 0.1 μm (optical spectrum)
Electrical apparatus	Ionising radiation
Static electricity	Ultrasonics
Lightning	Adiabatic compression & shock waves
Chemical reactions (inc. spont. ignition)	

This section covers some of the more common sources of ignition. Static electricity and chemical reaction / thermal instability will be covered in the next section.

Equipment Category	Explosive Atmosphere	Control of 'effective' ignition sources
Cat. 1G / D	Zone 0 / 20	No sources of ignition in normal operation, during expected malfunctions AND during rare malfunctions
Cat. 2G / D	Zone 1 / 21	No sources of ignition in normal operation AND during expected malfunctions
Cat. 3G / D	Zone 2 / 22	No sources of ignition in normal operation

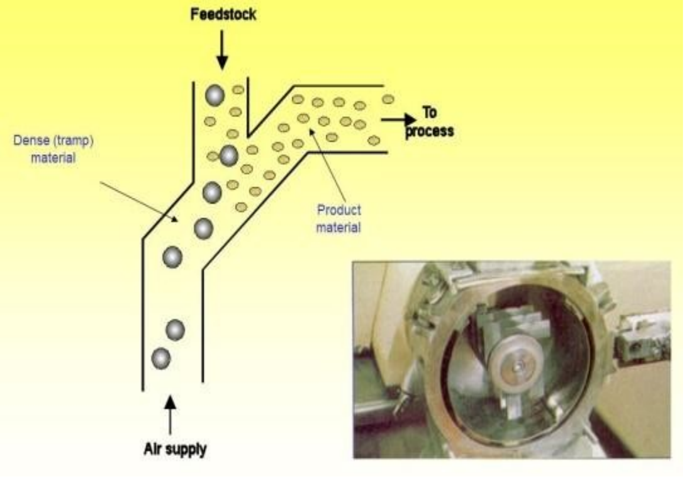
The table above shows the general philosophy behind matching the required level of ignition control to the likelihood of forming a flammable mixture.

In practice, some of the above can be avoided, for example, by management procedures or by specification of special (i.e. suitable) equipment.

However, many potential sources of ignition are present by virtue of the plant hardware, materials in use or mode of operation and as such, are inherent to the specific process and in need of control.

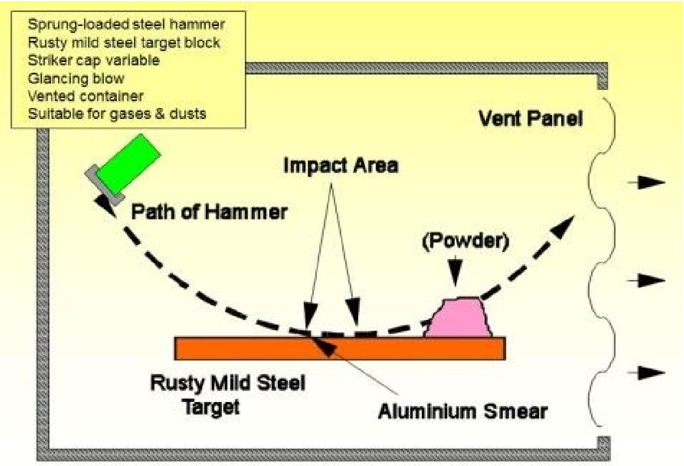
Mechanical Sparks

Ignition risks can arise when two hardened materials come into contact with force resulting glancing impact and friction sparks.



With certain materials, the impact energy can initiate an exothermic reaction (i.e. the Thermite reaction associated with aluminium, titanium, magnesium, zirconium and their alloys), resulting in highly incendive sparks of 'white hot' appearance.

Thermite friction sparks (particularly with rusty steel and aluminium) are known to be extremely energetic and capable of igniting many flammable gases, vapours, mists and dusts. In contrast, sparks which are formed between, say, steel on steel are much lower in temperature and energy.



Sometimes, pneumatic separators are used in the feed supply to remove ‘debris’, upstream from a Mill, for example; a good option where metal detection may not be 100 % reliable.

In reality, the ignition risk from any form of spark depends on the sensitivity of the fuel-air mixture. More stringent requirements are needed for Group IIB and IIC gases/vapours, because of their greater sensitivity, compared to Group IIA materials.

Research has been undertaken to evaluate the ignition hazard with respect to airborne dusts and this, together with similar work in Germany, has led to a better understanding of friction spark ignition capability e.g. the effect of the level of thrust at the point of impact.

In many instances, steel-on-steel friction and grinding sparks do not give cause for concern, due to the relatively slow rotational speeds of equipment i.e. if contact occurs at all, it is likely to result in increased surface temperatures rather than multiple sparks.

Therefore, potential sources of ignition can be eliminated by maintaining low circumferential (contact) velocities i.e. below 1 m.s-1.

Hot Surfaces

In accordance with **BS EN 1127-1:1998 'Explosive Atmospheres - Explosion Prevention and Protection'**, for gases, vapours and mists, the maximum surface temperature must not exceed:-

- 80% of the AIT value in C (even in the case of rare malfunctions) for Category 1 equipment (i.e. Zone 0 areas)
- 80% of the AIT value in C (during normal operation and in the case of rare malfunctions) for Category 2 equipment (i.e. Zone 1 areas)
- 100% of the AIT value in C (during normal operation) for Category 3 equipment (i.e. Zone 2 areas)

Hot surfaces can arise in many situations, both intentionally (e.g. drying operations) or spuriously (e.g. binding friction from Screw Conveyors and similar mechanised equipment, in this case the 1m/s does not apply. Hot particles from exhausts need to be eliminated in zoned areas, also.

Control of drying temperatures is of particular importance. To eliminate hot particles from direct fired systems, it is necessary to:-

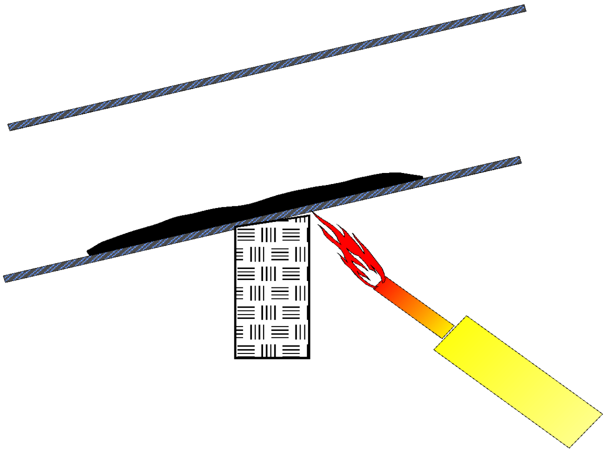
- Clean / filtered air if re-circulated
- Clean burners regularly
- Fit 3mm mesh on air inlet to restrict large (glowing) particles

The Dryer inlet and outlet temperatures must be restricted also. Typical values for an explosion protected Dryer are:-

- 50K below MIT cloud value
- 10-20K below Air-Over-Layer exotherm onset temp

Flames & Hot Gases

The most obvious risk of flame arises from unauthorised ‘hot-work’ and clearly procedures should be in place to ensure that this cannot arise – a near-miss was witnessed when an operator was sweeping dust from one side of a large sieve screen whilst welding work was being undertaken on the opposite side.



Hot work is a well-known cause of dust explosions and this activity needs special consideration. Instances are given in the open literature where (unknowingly) smouldering material has arisen inside the plant item, which then resulted in ignition on start-up.

In bulk storage areas, burning embers from the engine of trucks should be precluded by means of a certified flame arrester. Provided the necessary maintenance and inspection regimes, associated with this device (and any other heated surfaces e.g. engine block, manifold, etc.) are adhered to, this form of ignition hazard can be eliminated.

Electrical Equipment

Electrical apparatus used within the hazardous areas should be certified for the Gas Group (gases, vapours and mists/sprays) and the Temperature Class ('T' rating).

The maximum surface temperature of equipment ('T' rating) is the highest temperature attained in service under the most adverse operating conditions (but within the recognised tolerance) by any part or surface of the equipment which would be able to produce an ignition of the surrounding potentially explosive atmosphere.

The 'T' rating of equipment intended for use in flammable atmospheres and based on a max. ambient temperature of 40 °C, is listed as follows:-

Temperature Class	Max. Surface Temperature (C)
T1	450
T2	300
T3	200
T4	135
T5	100
T6	85

The criteria for selection of equipment is :-

- less than 2/3rds MITcloud
- AND
- more than 75K below MIT5mm layer

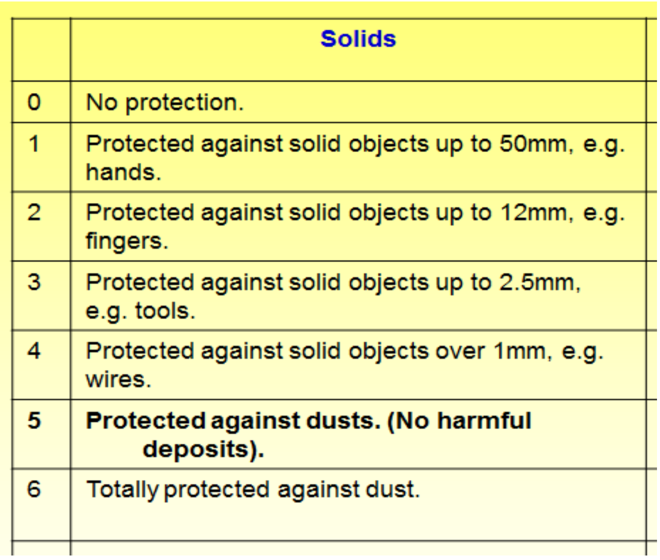
Using 'typical' wood fines as an example :-

MITcloud : 470 * 2/3 = 313 °C

MIT5mmlayer : 260 – 75 = 185 °C

Therefore, the required Rating is T4 – T6 (for max. 5mm thickness)

It is important to use the correct Ingress Protection (IP) rating also i.e. typically IP5X or IP6X for dusts) – the first and second digits refer to restricting dust and water ingress, respectively.



	Solids
0	No protection.
1	Protected against solid objects up to 50mm, e.g. hands.
2	Protected against solid objects up to 12mm, e.g. fingers.
3	Protected against solid objects up to 2.5mm, e.g. tools.
4	Protected against solid objects over 1mm, e.g. wires.
5	**Protected against dusts. (No harmful deposits).**
6	Totally protected against dust.

In general terms, if electrical equipment needs cleaning more often than daily to keep dust deposits to negligible thickness and it is not dust tight (IP6X), it should be replaced or relocated.

Overheating of dust layers on electrical equipment (e.g. motors) leading to a fire is usually a slow process. Dust layers should be removed regularly to control this problem and in any case, should not exceed 5 mm thickness.

Lightning

If lightning strikes a flammable atmosphere, ignition will always occur. Moreover, there is also a possibility of ignition due to the high temperature reached by lightning conductors.

Large currents flow from where the lightning strikes and these currents can produce sparks in the vicinity of the point of impact.

Even in the absence of lightning strikes, thunderstorms can cause high induced voltages in equipment, protective systems and components.

In practice, the probability of a lightning strike depends on the specific location of the site and a specialist should be consulted to ascertain whether additional precautionary measures are required.

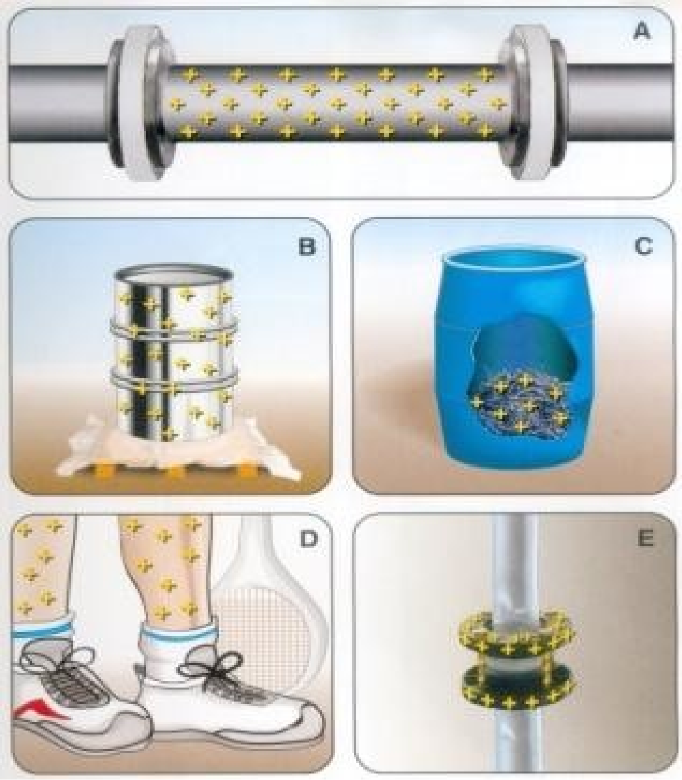
As a general precaution against external sources of ignition, all vents handling flammable gases and vapours should be fitted with a suitable flame-trap!

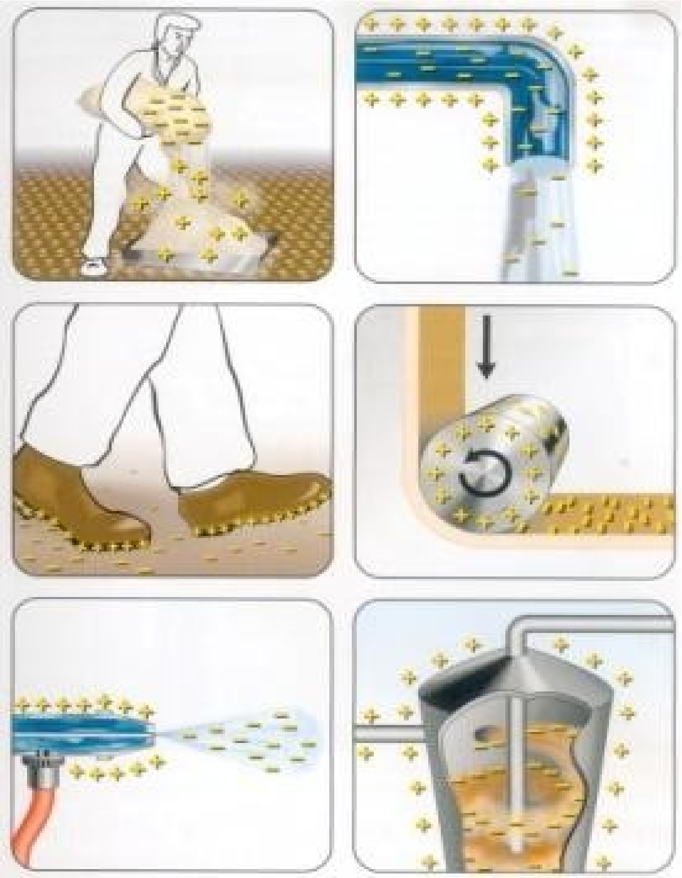
Section 5: Static Ignition & Thermal Instability

Static electricity is part of everyday life and is generated when materials come in to contact with each other and then separate i.e. electrostatic charging occurs at the interface. The phenomenon is known as a 'contact electrification' and this gives rise to a ‘streaming’ or charging current.

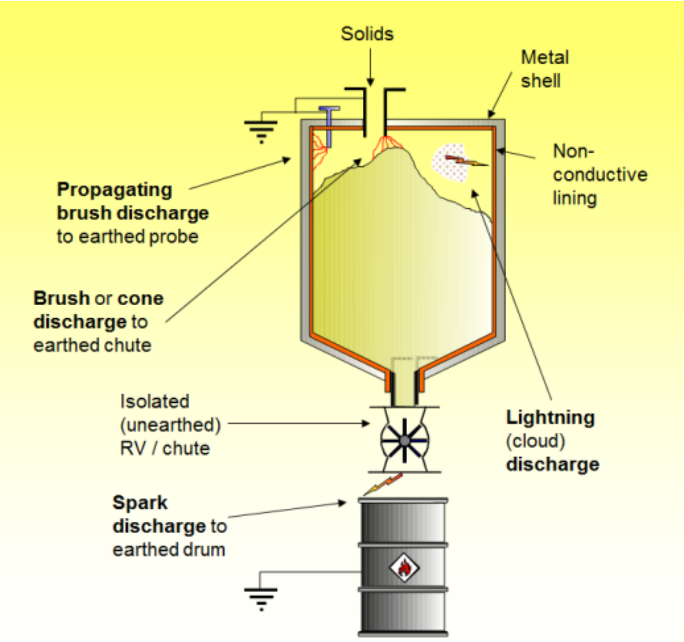
Potential electrostatic charging hazards are shown above and include fluid flow in pipework, drum charging operations, walking across a floor, pouring powders, film transport rollers, spraying, etc.

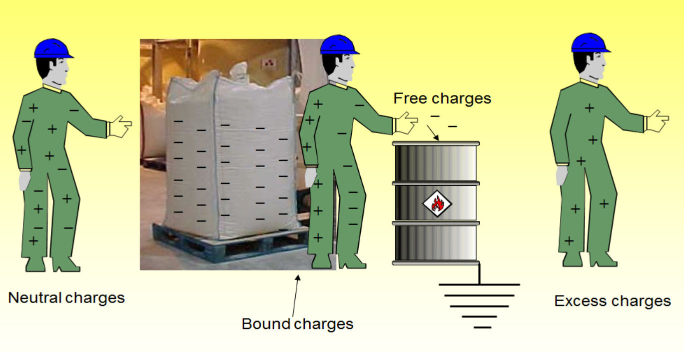
ATEX Establishing a Basis of Safety





The electric field produced can give rise to different types of discharge, with differing energy levels. The highest charging currents arise from the use of electrically insulating materials (e.g. PTFE lined equipment, Poly-Tubs, plastic sheeting and insulating (low conductivity) liquids such as Toluene, n-Hexane and many others.





Operatives isolated from earth via their footwear or the flooring can become charged unknowingly, simply by standing within an electrostatic field.

For example, at rest, humans are likely to be charge neutral i.e. no significant excess positive or negative charge.

However, if they stand next to a highly charged surface (e.g. negatively charged FIBC), the charges on their body will ‘polarise’ i.e. the residual negative charges will be repelled and the positive charges attracted.

Whilst in this position, if the person touches an earthed item, the free (negative) charges will flow to earth and as he or she walks away, they will be left with net positive charge, which is a potential source of ignition.

Charge generation per se is not the issue; the problem is the accumulation of charge because it can create a source of ignition.

The most basic precaution against electrostatic ignition is earthing - the structure of the plant and associated vessels/equipment are a potential source of electrostatic charge accumulation and therefore, must be earthed to avoid this risk.

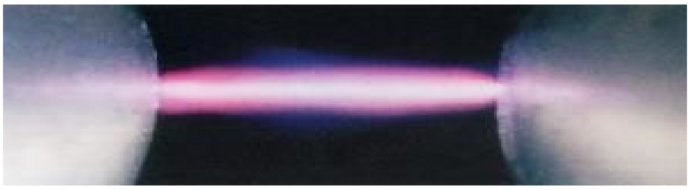
All metal items and fittings (e.g. funnels, metal spirals in flexible LEV trunking, etc.) should be in good contact with each other and with earth. For example, Blo-line / Morris couplings have an integral earthing strip (as shown LH photo) to ensure electrical continuity through the coupling and along the pipework.

Electrical continuity checks should be made before equipment is brought into use and following any maintenance work. Frequently, however, earthing failures are evident during audits e.g. unattached / ungrounded metal reinforcing helices in flexible trunking, grilles in loading chutes, etc.

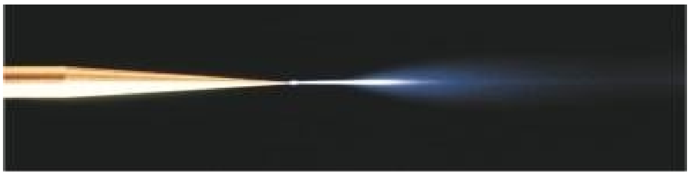
The requirements for resistance levels are essentially those normally used by electrical engineers i.e. LESS THAN 10 to earth. In practice, higher resistances may be used (up to 106 Ω) but only where the reason for the high resistance is known and controlled.

ATEX Establishing a Basis of Safety

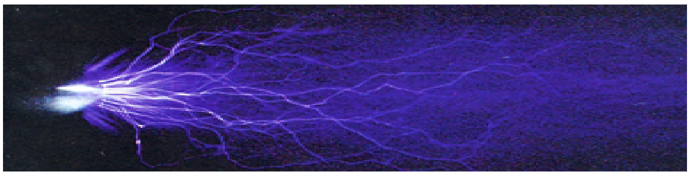
Types of Discharge



Spark: Occurs between two conductors (the plasma channel is over the entire gap)

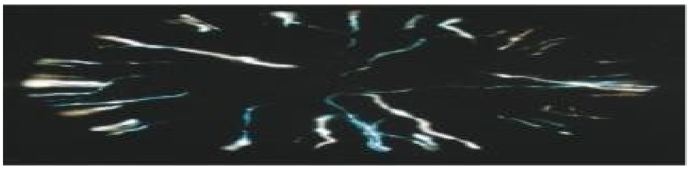


Corona: Point discharge with no plasma channel



Brush: Occurs between a charged non-conducting surface and a (rounded) earthed conductor or electrode

Propagating Brush: Polarised insulating sheets of very high charge density



Cone: Occurs from highly charged, high resistivity granular materials

People

People who are insulated from earth (by their footwear or the flooring) can easily acquire and retain an electrostatic charge. If the MIE of the flammable atmosphere is lower than 30 mJ, consideration needs to be given to grounding personnel i.e. use of 'charge dissipative' footwear and flooring.

In addition, clothing should be as close fitting and should not be removed or unfastened within the hazardous area.

Insulating Plastics

Insulating plastics can present a risk of ignition in zoned areas, also. 'Brush discharges' with energies up to 4 mJ can occur from charged insulating surfaces and this is well in excess of the minimum required for ignition of low flash point solvents (e.g. Acetone, Toluene, Methanol, etc.) and sensitive airborne powders.

Thus, the exposed surface areas of insulating surfaces need to be restricted, as shown below.

Restrictions on Surface Area (cm2) – Sheets

Gas Type	Group IIA	Group IIB	Group IIC
0	50	25	4
1	100	100	20
2	No Limit	No Limit	No Limit

For example, high resistivity plastics exceeding 100 sq.cm in area cannot be used with IIA or IIB solvents in Zone 1 areas, unless it can be shown that charge generation (or incendive discharges) will not arise even in the case of likely malfunctions. Clearly, this excludes all but the smallest of plastic items.

Thus, an electrostatic hazard assessment requires a systematic study of where (and the levels of) charge that can be generated, whether it can accumulate, the type and energy of the discharge and the ignition sensitivity of the flammable atmosphere.

Thermal Instability

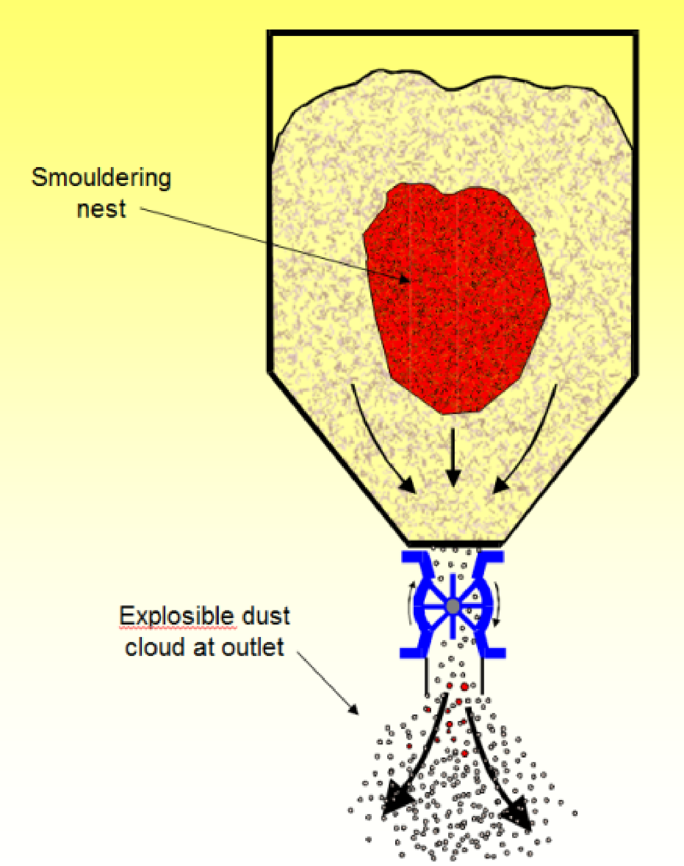
General guidance for risk control is specified in DSEAR Section 6.4 (Risk Reduction) and one of the key elements is 'Avoid Adverse Conditions'. Essentially, in heated equipment such as Dryers, Hot Boxes, etc.), this relates to the identification and control of areas where hot dry material can collect (Dryer inlets/outlets, Mechanical Conveyors, Mills, etc.).

To preclude highly energetic 'propagating brush discharges', special types of FIBC are required. Type A bags (which have no dissipative properties and high breakdown strengths) should **NOT** be used with explosible powders.

- A - no special requirements
- B - breakdown FIBC wall < 4 kV
- C - resistance to earth from any location < 100 M.Ω
- D - interwoven conductive threads not connected together

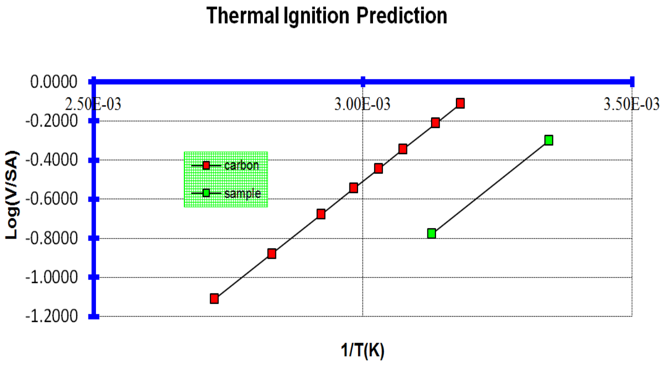
In most cases, small scale tests such as DTA or DSC? will not be sufficient; Diffusion Cells, Aerated Cell or Air Over Layer tests are preferred since the availability of air during self-heating can have a profound effect. The key features are the onset temperature of self heating Tonset, the points at which the exotherm becomes marked Tmarked (> 5 K/min) and rapid Trapid (> 50 K/min).

Thermal stability test results can indicate significant self-heating hazards e.g. smouldering nests inside bulked product, smoulders on ledges inside Dryers, etc. Some materials exhibit relatively low exotherm onset temperatures from about 130 °C and high peak temperature of > 700 °C, even on the small scale.



However, these tests are still for screening purposes because they don't allow the effect of scale to be determined.

Where exothermic activity near the process operating temperature is likely, further 'Basket Tests' will be required to allow safe operating temperatures to be quantified. The tests are run isothermally in wire baskets of different size.



The effect of scale is predicted by plotting scale (volume/surface area) against the reciprocal self-heat temperature TC (K). An example is given as follows:-

$$\text{Log (V/SA)} \approx [2189.4 / T_c(K)] - 6.758$$

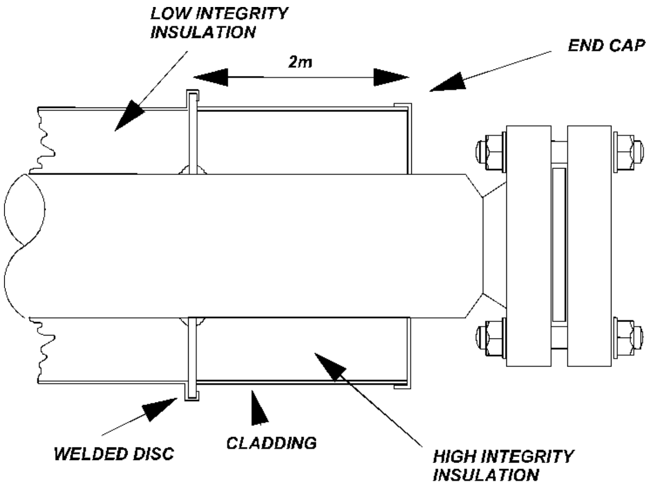
The self-heat onset temperature will increase as the surface area of the bulked material increases. For example, if a material starts to self-heat at 93 °C as a 1 m3 mass, thermal predictions may show that as a 50 cm thick layer, the onset would be nearer 107 °C due to greater cooling by the larger surface area.

Fibrous Insulation

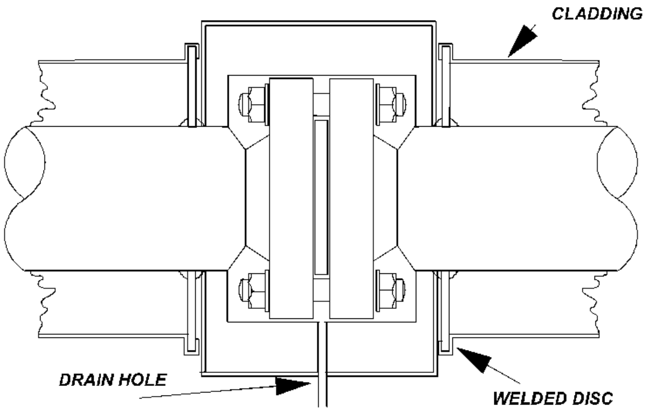
Thermal instability can also occur in **fibrous insulation**. The potential ignition / fire hazard arises from auto-oxidation of insulation - a gradual exothermic oxidation of combustible material, accompanied by the generation of heat. Hence, auto-oxidation needs to be controlled whenever there is a possibility of insulation being contaminated, particularly by oils at elevated temperatures.

Auto-oxidation and escalation in temperature is exacerbated by the inherent insulation (low thermal conductivity) properties and high surface area. Hence, it is often prudent to use a closed-cell type of insulation on hot oil systems, particularly around joints, known leakage points, etc. since this type of insulation is not prone to oil seepage or wetting.

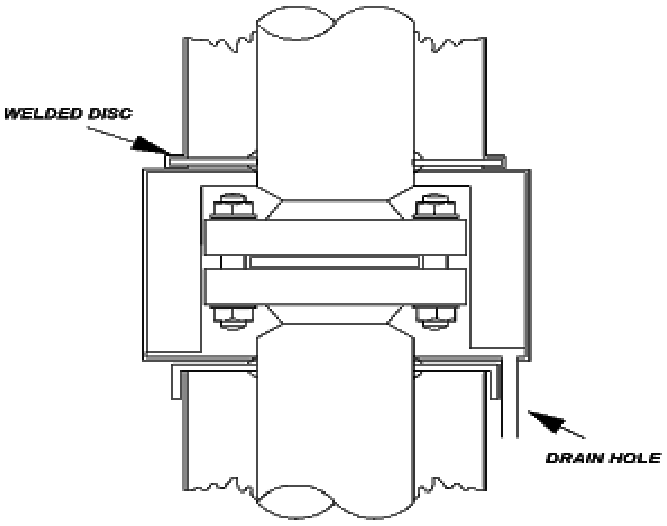
NOTE: Great care is needed when removing contaminated lagging as this too can spontaneously ignite. Oil contaminated lagging should be removed only under a **HOT WORK** permit.



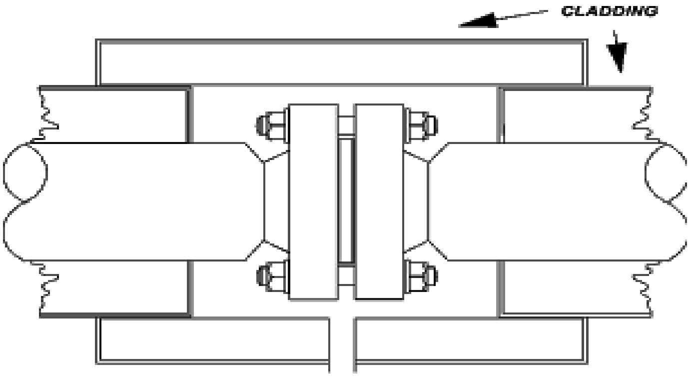
WELDED DISC DESIGN TO FORM BARRIER BETWEEN INSULATION TYPES (UNINSULATED FLANGE)



WELDED DISC DESIGN WITH FLANGE BOX - HORIZONTAL (INSULATED FLANGE)



WELDED DISC DESIGN WITH FLANGE BOX - VERTICAL (INSULATED FLANGE)



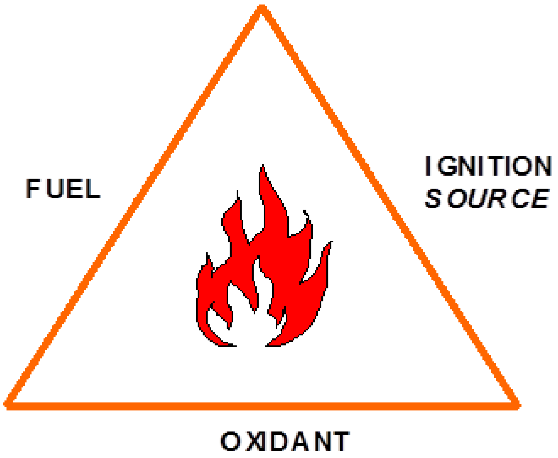
STANDARD METHOD FOR PIPE FLANGE - HORIZONTAL

Section 6: Prevention

As mentioned in the first 'introductory' section, prevention of the formation of an explosive atmosphere, including the application of appropriate ventilation, is an acceptable approach to control of risk.

Prevention techniques can be simple, dilution for example, equally applicable to certain types of solvent handling operations and evaporative Ovens / Dryers as dust extraction systems.

The question is - can we under all normal and abnormal operations control (i.e. eliminate) one of the **THREE** basic components for combustion?



Codes of practice, for Dryers and Ovens in which flammable substances are released, set out basic design criteria **(dilution of the vapour)**. This is aimed at processes where the flammable VOC concentration exceeds 3 % of the Lower Explosive Limit.

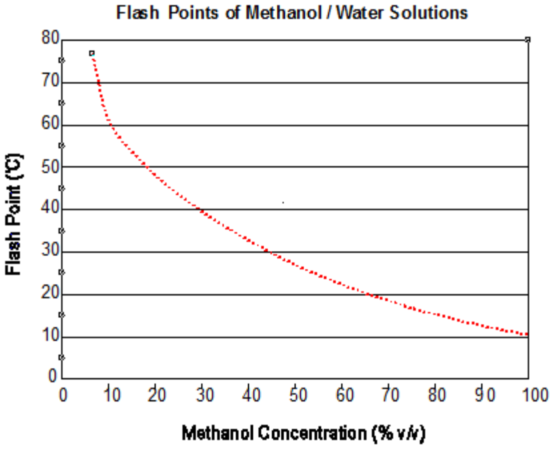
Essentially, the 'maximum admissible quantity of flammable substance' needs to be determined and controlled against the 'minimum forced ventilation flowrate' in order to maintain conditions below the 'maximum admissible concentration' below the LEL. This includes any short-term operations. Indeed, a formal **HAZOP** study, which examines ALL of the conditions which can lead to the formation of extensive flammable atmospheres inside plant equipment, should be undertaken to allow the necessary ventilation rates to be determined.

Dilution

Following on from the first Introductory Article, water miscible solvents can be made 'safer' simply by adding water, to an alcohol for example. If the maximum ambient temperature is (say) 25 ˚C, using a 5K safety factor, concentrations up to 40 % v/v would be permissible.

ATEX Establishing a Basis of Safety

Dilution of the liquid is sometimes employed where solvents are used for cleaning purposes, thereby eliminating the formation of hazardous areas (and the potential for ignition) both inside and outside equipment.

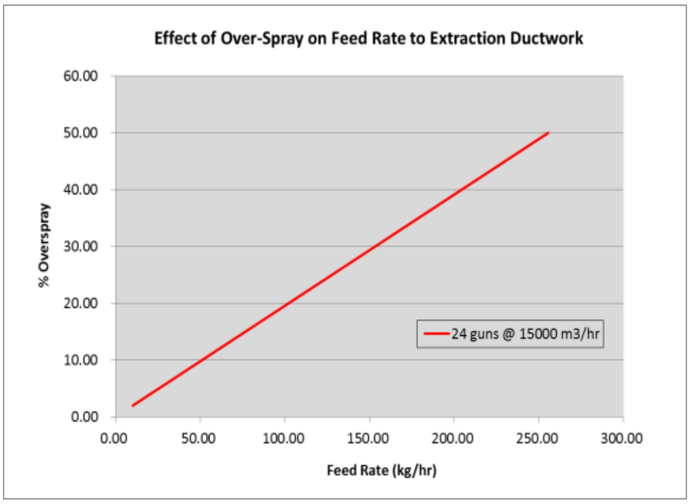


Ventilation

Ventilation (or rather Extraction) can be employed to **dilute airborne dust**, in a spray coating operation for example.

Typically, a primary source of release will exist within the confines of the spray / extraction hood (i.e. 'concentration gradients' will exist between the source [spray head] and the ventilated surroundings, allowing localised flammable atmospheres to occur) but, given the correct level of ventilation, flammable atmospheres (hazardous areas) should not extend in to the extraction system.

The necessary extraction rates are determined from the spray rates. For example, at a mass feed rate of 355 g.min-1 per gun at 100 % and 24 gun operation, assuming 50 % overspray, the mass feed rate to the extraction system is 256 kg.hr-1.



As a rule, the maximum concentration within the ductwork should be 25 % MEC (typically between 10 – 100 g.m-3) and in view of the fact that the airflow through the extraction ductwork forms part of an explosion safety system, this should be monitored or (at least) afforded a flow switch to indicate poor performance i.e. reduced flow.

Ventilation also plays a key ‘preventative’ role in gas-fired systems e.g. Boilers, Burners, etc. Efficient and effective ventilation can render a Boiler House as Zone 2 (NE) i.e. of negligible extent.

Gas detection has a role to play also, when interlocked to the supply and thereby limiting the persistence of the hazardous area. The siting of the detector head is critical, however; governed by neighbouring equipment and local air movement due to thermal gradients and forced or natural ventilation.

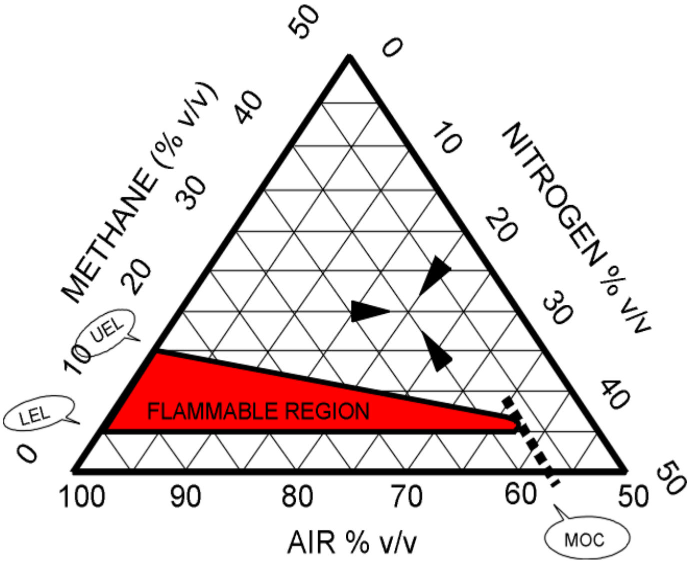
Smoke tests (or childrens’ ‘Bubbles’ – **YES, BUBBLES**) can be used to check that there is free movement of air around the equipment i.e. to ensure that the proposed ventilation is effective at the point of interest and the Zone 2 NE (negligible extent) designation can be upheld.

Inerting

Inerting is another preventative technique but here, we are controlling the Oxidant concentration rather than the fuel. The diagram (below) expresses the flammability characteristics (or 'envelope') for methane, depicting lower and upper explosive limits and the 'nose' of the curve at which the MOC occurs. The principle of the flammability envelope also holds for vapours and airborne dusts i.e. as the oxygen concentration is reduced, the lower and upper flammability limits converge to a point where flame propagation cannot be sustained.

Inert gas blanketing or purging is commonly used as the sole basis of safety. Thus, it is imperative to maintain the reduced oxygen level inside the processing environment whilst the potential source of ignition may be present.

It can be seen that a reduction in oxygen content does not change the lower limit value but markedly reduces the upper limit. This is because oxygen is in excess at the lower flammable limit.



ATEX Establishing a Basis of Safety

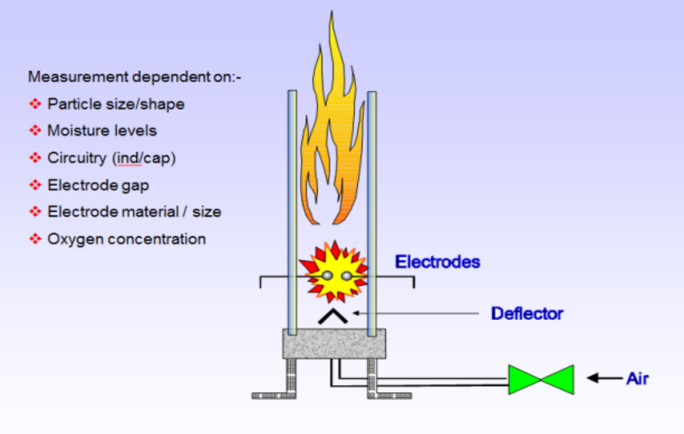
Generally, a safety factor is applied to the required oxygen level (MOC or LOC [Limiting Oxygen Concentration]) to take account of changes in environmental conditions and also, to allow for inaccuracies that may arise when monitoring or sampling the internal atmosphere - a safety factor of 2.0 - 3.0% below the limiting value is recommended.

Literature information (NFPA 69 Explosion Prevention Systems Appendix C Table C-1 – National Fire Protection Association) indicates an MOC value of 9.5 % by volume for Toluene, where nitrogen is the purge gas. Hence, the design basis value would be a maximum of 5 % oxygen by volume under normal running conditions with shut down at 7.5 % oxygen by volume.

It must be borne in mind that MOC values like flammability limits, are pressure and temperature dependent. Also, gases other than nitrogen can be used for inerting purposes e.g. halogenated compounds, water vapour, carbon dioxide, etc. and their efficiency is dependent upon their gaseous specific heat capacity.

Inert gas blanketing/purging is used in many industries as a Basis of Safety e.g. Metal Purification, Pharmaceuticals, Coal Handling Plant (Mills), etc.

Even ‘partial inerting’ has benefits. This is where the concentration of the oxidant lies above the MOC value but below the prevailing atmospheric level. Flame propagation can still occur but at a reduced rate, depending on the extent of oxygen depletion. In such cases, the gas/vapour-air or dust-air mixtures will lie within the flammable envelope but at a point where the explosive limits are closing.



This influences not only explosion severity but also ignition sensitivity - combustion through the mixture can still occur but the explosion effects will be reduced. Ignition sensitivity will decrease also. A reduction in oxygen content can result in marked increases in both hot surface ignition temperature and minimum ignition energy.

As discussed in previous sections, we can base safety on ‘Elimination of Ignition Sources’ IF the basis for the hazardous area classification (Zoning) is sound, **ALL** equipment within the Zones is correctly ATEX certified AND we don’t introduce ‘user’ or process intrinsic ignition sources such as static electricity, smoulders, hot surfaces, etc.

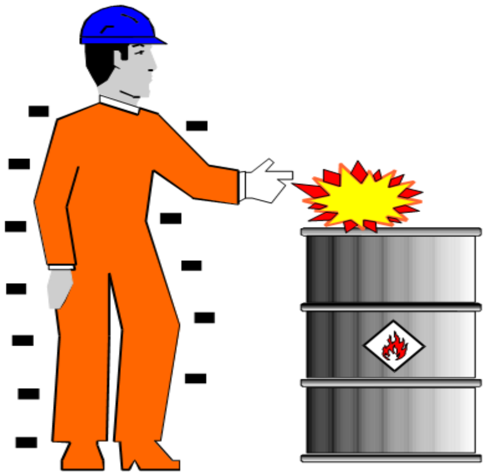
Control of Ignition Sources

We cannot stress this enough – without knowing the ignition sensitivity of the material (be it gas, vapour, mist or dust), we cannot assess the ignition potential with any accuracy.

Likewise, we need to know the extent of the hazardous Zones accurately so we can assess which operations / equipment can give rise to the ignition sources.

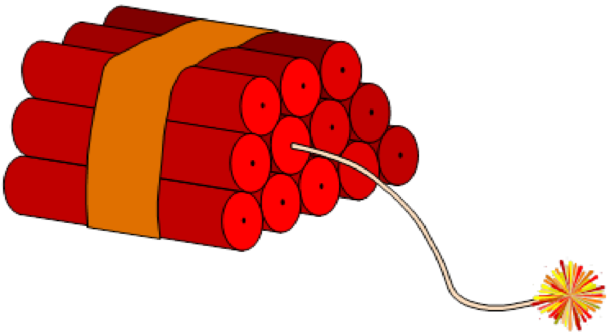
Intrinsic ignition sources are those which exist solely due to the operation, for example:

- Electrostatic sparks (poly-liners, unearthed personnel, etc.)
- Thermite sparks (aluminium scoops, foil, etc.)
- Mechanical friction (screw feeders, milling, etc.)
- Pyrophoricity (metal powders, catalysts, etc.)
- Smouldering deposits (dryers, grinders, etc.)
- Auto-ignition (dryers, furnaces, etc.)



So, in essence, ignition prevention depends on how thorough you are AND how competent you are in identifying sources of ignition which might become EFFECTIVE i.e. capable of igniting the flammable atmosphere under the prevailing process conditions (taking in to account temperature, concentration, moisture level, particle size, etc.).

But the consequences can be huge if you get it wrong!



Section 7: Protection

The ***'protection'*** concept is based on the assumption that ignition and an explosion (gas, vapour, mist or dust) may arise and steps need to be taken to mitigate the effects, thereby safeguarding personnel and (as far as practicable) maintaining the integrity of the plant. The options available are dependent on the plant vessels / layout and the characteristics of the materials. There is a choice of two designs.

An **Explosion Pressure Resistant Design (EPRD)** does not allow for any deformation of the vessel whereas an **Explosion Pressure Shock Resistant Design (EPSRD)** does - i.e. deformation is acceptable, but not total failure.

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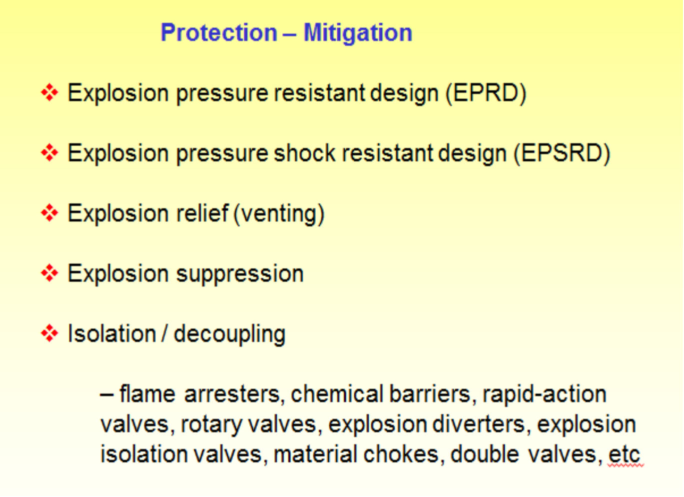


Protection – Mitigation

- Explosion pressure resistant design (EPRD)
- Explosion pressure shock resistant design (EPSRD)
- Explosion relief (venting)
- Explosion suppression
- Isolation / decoupling
  - flame arresters, chemical barriers, rapid-action valves, rotary valves, explosion diverters, explosion isolation valves, material chokes, double valves, etc

Explosion Pressure Relief

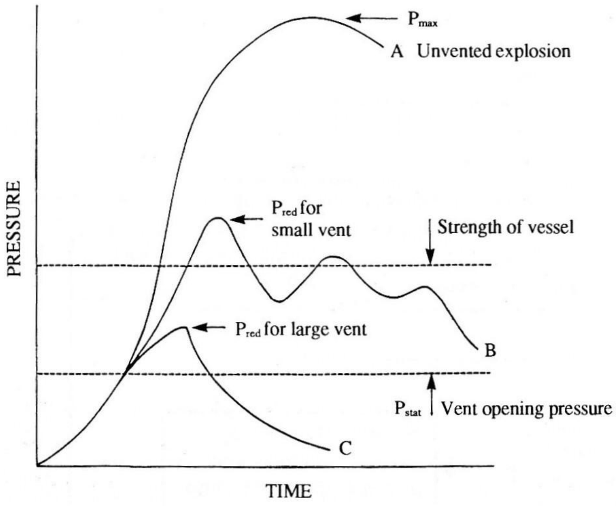
Explosion pressure relief is perhaps the most common but essentially there is a ***'loss of containment'*** i.e. process material and/or fume will be emitted from the protected vessel during the explosion. Conversely, explosion suppression and total explosion pressure containment systems do not give rise to a release of process material.

Venting

Explosion venting is a protective measure preventing unacceptable high explosion pressure build-up inside vessels / enclosures. Normally explosion venting is applied such that the maximum reduced explosion pressure (Pred,max) does not exceed the known design pressure of the vessel; the lower the vent opening pressure (Pstat) and the larger the vent area, the lower the reduced explosion pressure.

Moreover, ALL parts of the enclosure, including valves, access ports, **ductwork**, etc. exposed to the explosion pressure, must be taken into account when estimating the design pressure of the vessel – this is to ensure that the relief of the explosion pressure is accomplished in a controlled manner.

Venting does not prevent an explosion, it limits the explosion pressure. Hence, flame and pressure effects outside the enclosure and flying debris must be anticipated and accounted for. To preclude this, flameless venting devices (depicted below) may be used – this form of venting is particularly useful for plant sited in (or close to) the middle of the work area; otherwise, long vent ducts would be required to safely vent the explosion outside the confines of the building.



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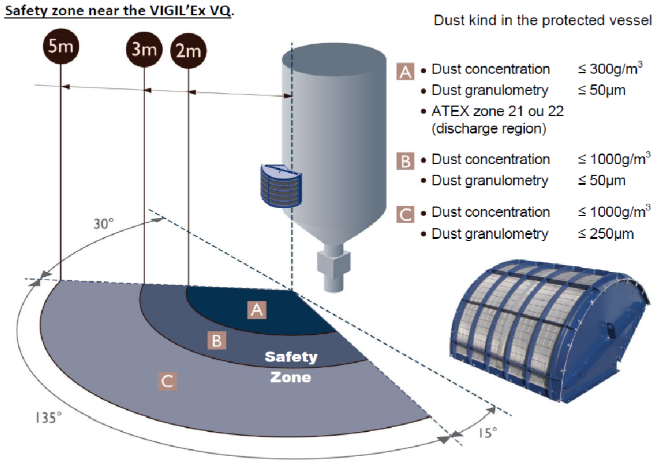
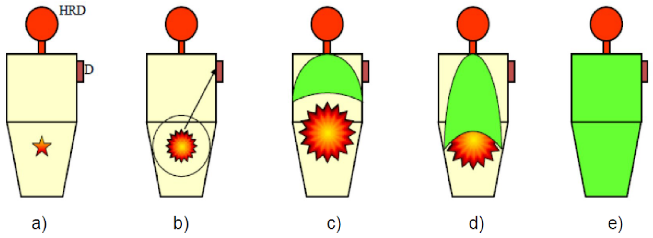


Explosion Suppression

As mentioned above, explosion suppression does provide containment of the 'reduced explosion pressure' (Pred). This is achieved by detection of the incipient explosion i.e. in its early stages. Whilst the combustion is taking place (most of the time quite rapidly over a few milliseconds), once detected, suppressant is injected in to the growing fireball to quench the flame.

The predominant effect is absorption of heat, temperature reduction and stoppage of flame transmission. Once again, ALL parts / components of the vessel must be taken into account when estimating the design pressure.



In practice, the quantity of suppressant (number of suppressors) and their location will depend on the violence of the explosion (Pred and Kst from dust testing), the geometry of the vessel and its design pressure.

Chemical Suppressor

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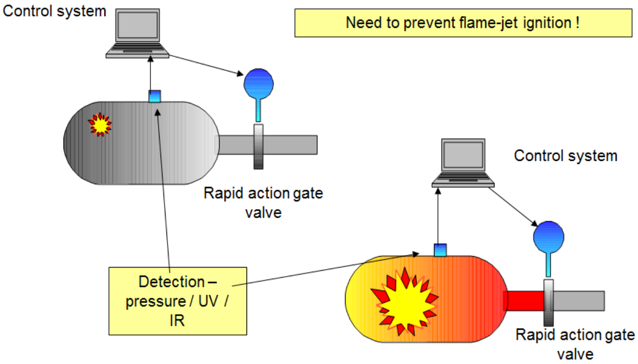
Explosion Pressure Containment

With the exception of some milling operations, as a safety concept, explosion pressure containment is less common. This is due to the high design strength needed – typically of the order 8 – 10 bar.g for dust explosion containment. Common gases and hydrocarbons have lower peak explosion pressures of about 6 – 8 bar.g.

It is important to recognise, however, that ANY explosion protection system MUST cover upstream and downstream interconnections i.e. it is imperative to provide isolation to prevent propagation of burning particles, flame and pressure.



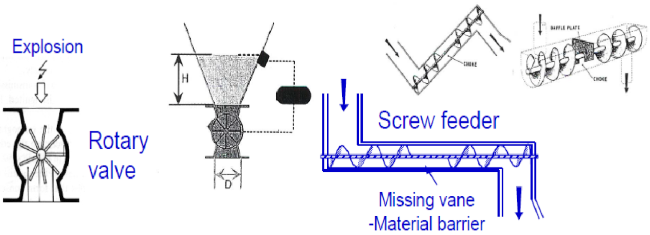
Active Slam-Shut Valve

Isolation

Isolation can take the form of an ATEX certified rotary valve or active of passive slam-shut (rapid action) valve, chemical extinguishing barrier, product choke, etc. as described in prEN 15089 Explosion Isolation Systems.

For complete isolation (e.g. by use of a slam-shut valve), the design pressure must be applied up to the isolation device. Hence, any ducting or pipework up to this point would need to withstand the maximum anticipated pressure i.e. Pred or Pmax.

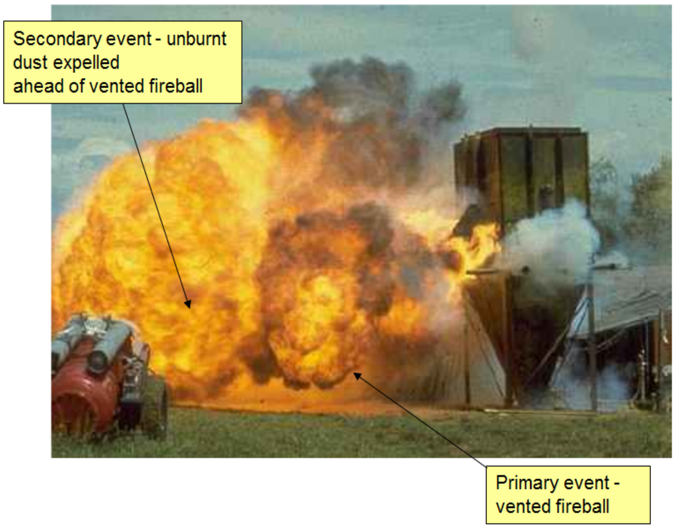
A typical arrangement is shown in the schematic below. The closure time of the rapid action valve, together with the response time of the detection/control system and flame speed, defines the required minimum distance (L) from the source of the explosion – typically L > 5000 mm.



A vented explosion must discharge to a safe area and often, this requires the use of a vent duct. The action of venting, in most cases, will be accompanied by ejection of burned and unburned gases and flames and measures must be taken to ensure that nearby plant and personnel will not be at risk from the vented fireball.

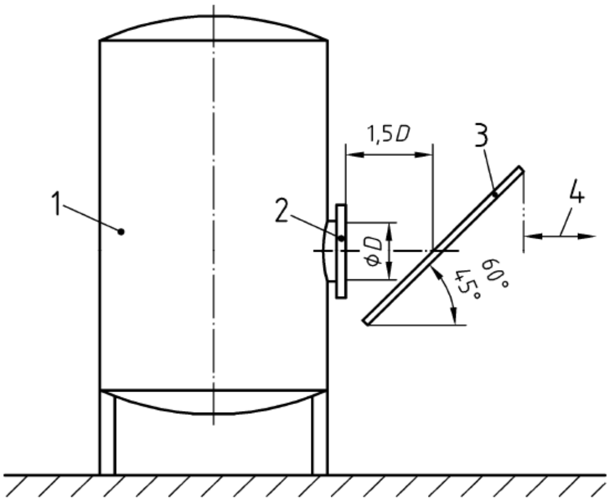
It is important also to note that a vent duct will increase the back-pressure during the relief process requiring a greater pressure resistance for equipment and vessels.

Flames ejecting from a vent opening will spread in all directions but especially in the main lateral venting direction due to inertia. Moreover, the flames will represent a thermal radiation hazard. In certain cases, a deflector plate (depicted below) can be used to limit the length of the ejected flame.

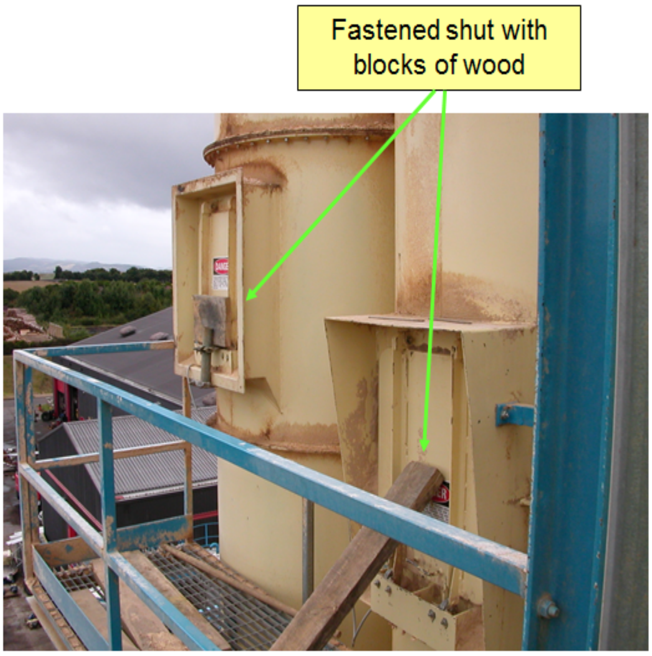


Secondary event - unburnt dust expelled ahead of vented fireball

Primary event - vented fireball



In addition, if the vent is situated in the side wall, the recoil force on the enclosure must be considered in the design. Also, as shown in the photograph above, unburned dust can be ejected ahead of the fireball during venting increasing external thermal radiation and overpressure effects.



Fastened shut with blocks of wood

As part of the isolation concept, equipment must be shut down automatically, in the event of an explosion, to prevent transfer of burning material, etc. With venting, this is normally achieved by sensors fitted to the vent panel. Of course, this should not result in frequent spurious shutdowns, since some will find ways of by-passing the problem – by means of wood and scaffolding poles to keep vent doors shut, for example, as shown. The **CORRECT** course of action would have been to examine why the explosion doors keep opening!

When fitting explosion protection, from a process viewpoint, it is important to think about any repercussions. One example is the use of **Rotary Valves** for explosion isolation purposes as this is often contentious due to the likely ***'wear rates'*** and the need to maintain certain tolerances (in particular, the gap between the blades and the casing).

Another example is the use of Flap-Valves in dust laden ductwork. The on-going 'user obligations' regarding inspection and maintenance of such items is not always appreciated.

For example, periodic inspection checks must be undertaken to ensure that the explosion isolation capability does not deteriorate (e.g. due to corrosion, abrasion, dust built up on the flap, dust build up inside the body of the flap valve).

The positioning of explosion vents on Dust Filters is important too, to ensure that the internal filter membranes do not obstruct (compromise) the protection.

Vent panels sited close to membranes can result in an increase in the 'reduced explosion pressure' (Pred value) and over-pressurisation of the vessel – the filter bags can be blown out of the vent on activation.

A further consideration is that of providing automatic fire suppression since Filters can be terminally damaged by secondary thermal stresses due to burning bags or product, following the explosion.

Section 8: Management Procedures

Do we need to take precautions, as part of our managerial responsibilities and if so, why and to what extent? Well, there may be a risk of injury or fatality (to Plant Operators or members of the public), there are Statutory Requirements (Legal Obligations) which we must adhere to and there are consequences when things go wrong:-

- Interruption to the business
- Fines for breach in legislation
- Loss of market share
- Loss of customer confidence
- Harm to corporate image

Risk Matrix

We need to ask ourselves, is the risk we have identified, high enough to justify the investment in order to reduce it to a tolerable level. To this end, a commonly used Risk Matrix is shown below.

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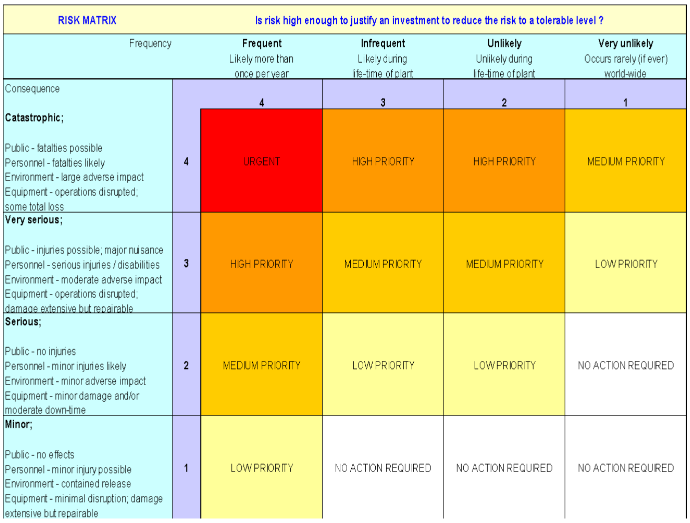


RISK MATRIX		Is risk high enough to justify an investment to reduce the risk to a tolerable level ?			
Frequency		**Frequent** Likely more than once per year	**Infrequent** Likely during life-time of plant	**Unlikely** Unlikely during life-time of plant	**Very unlikely** Occurs rarely (if ever) world-wide
Consequence		4	3	2	1
Catastrophic; Public - fatalties possible Personnel - fatalties likely Environment - large adverse impact Equipment - operations disrupted; some total loss	4	URGENT	HIGH PRIORITY	HIGH PRIORITY	MEDIUM PRIORITY
Very serious; Public - injuries possible; major nuisance Personnel - serious injuries / disabilities Environment - moderate adverse impact Equipment - operations disrupted; damage extensive but repairable	3	HIGH PRIORITY	MEDIUM PRIORITY	MEDIUM PRIORITY	LOW PRIORITY
Serious; Public - no injuries Personnel - minor injuries likely Environment - minor adverse impact Equipment - minor damage and/or moderate down-time	2	MEDIUM PRIORITY	LOW PRIORITY	LOW PRIORITY	NO ACTION REQUIRED
Minor; Public - no effects Personnel - minor injury possible Environment - contained release Equipment - minimal disruption; damage extensive but repairable	1	LOW PRIORITY	NO ACTION REQUIRED	NO ACTION REQUIRED	NO ACTION REQUIRED

More detailed forms of the matrix with costs, event frequencies, etc. are available but this shows the general idea.

Today, risk assessments are common place and used in all walks of life, often without a proper understanding of the true meaning i.e. risk is the product of probability (of the undesired event) and consequence.

The categorization of a risk as insignificant does not necessarily mean that it will be perceived as such by those affected; it relates rather to the action required by the decision maker.

Neither does tolerable mean acceptable - it refers to the willingness to live with a risk to secure certain benefits and in the confidence that it is being properly controlled.

To tolerate a risk means that we do not regard it as negligible or something we might ignore, but rather as something we need to keep under review, and reduce still further if, and as, we can (Hazard Identification and Risk Assessment - Geoff Wells, IChemE 1996).

Management Obligations

Management obligations are wide ranging and for that reason, they can be quite daunting. However, some simple measures can be put in to place which not only help massively reduce risk but also do it both effectively and economically.

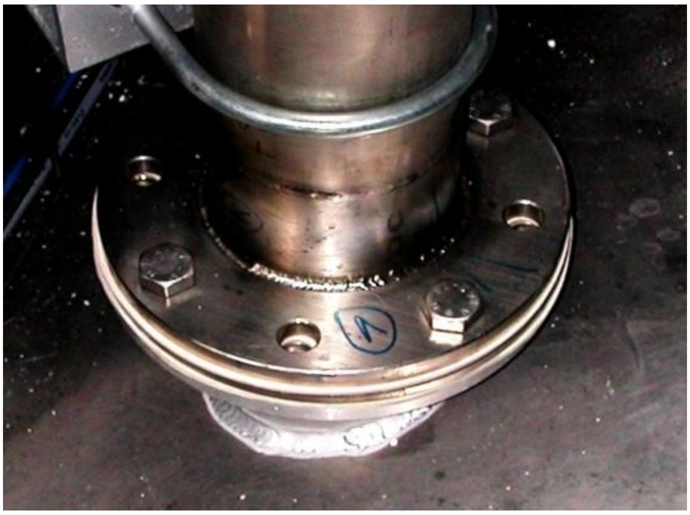
For example, bearing in mind the need to control releases of the 'hazardous material', all equipment must be well maintained and subject to regular inspections, in line with good engineering practice.

The use of improper seals/joints **IS NOT** acceptable. For example, 'gaffa tape' should never be used on leaking joints. Moreover, there is a tendency for this type of temporary fix to become permanent. Likewise, seals (and replacement thereof) need to be robust to reduce the extent of dust egress.

Items of plant and equipment must be sealed effectively i.e. not simply relying on gravity to hold a door or panel shut. For example, often inspection hatches are not bolted down – although this might be considered unnecessary for (say) granular materials, it sends the wrong message to operators and maintenance staff (e.g. there should be a consistent approach).

Such items should be bolted shut and form an effective seal; although this may not lead to the formation of a hazardous area per se, fugitive emissions from poorly sealed plant will give rise to housekeeping issues.

Some inspection hatches, which by their nature are opened routinely, should be sealed and afforded a 'quick-release' opening mechanism e.g. sprung-loaded, whilst other 'access' panels should be sealed and bolted shut.



Air-jetting (on dust deposits) must not be used - this simply moves dust around in to spaces which are even more inaccessible and it aggravates the problem. Use of dust extraction points (where provided) or vacuuming when opening up equipment should be encouraged - this will help reduce the cleaning frequency.

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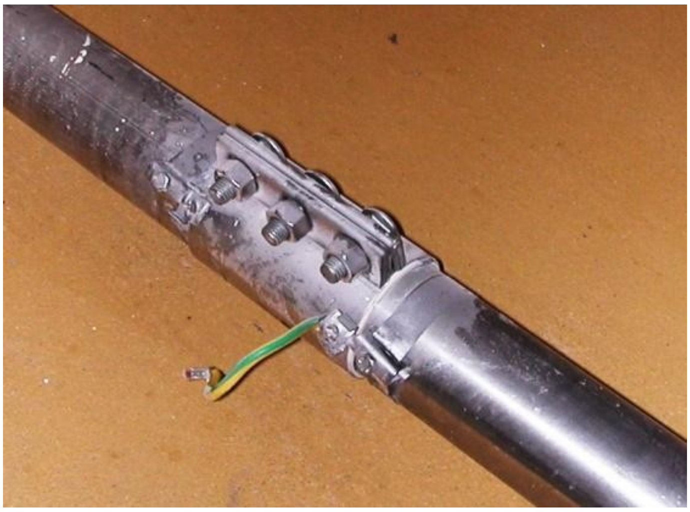
If extraction is provided for dust control, make sure the 'capture' velocities are correct for the materials in use. Also, all too often there is no indication of poor performance i.e. low flow, so fit a low-flow (LF) alarm with low-low-flow (LLF) trip. If the extraction fails, you'll know about it rather than throwing manpower at what appears to be more and more dust deposits!

From an operational (and safety) viewpoint, Conveyors should comprise one or a combination of the following - blockage detection, tracking sensors, motor overload protection, rotation sensors, etc. and **ALL** metal items should be bonded to earth.



Procedures must be in place which ensure that Hot Work is controlled. Indeed, **ALL** plant personnel must be made aware of both the potential ignition/explosion hazards associated with their plant and the means of control. To this end, formal **DSEAR / ATEX** Training Sessions should be conducted on a regular basis and Attendance Certificates issued.

INBUREX
CONSULTING

Certificate of Training

The Dangerous Substances
& Explosive Atmosphere
Regulations (DSEAR) 2002

This is to certify that

John Smith

attended the above awareness course at
An Industrial Plant
London on 20th September 2011

Nigel Maddison
Trainer :- ……………………………
Nigel Maddison

Presented by
Inburex (UK) Ltd, 14 Woodlands Park, Hyde, Cheshire SK14 3ST
Tel. 01618-829469; email:inburex@globalnet.co.uk

HAZOP studies should be considered. This is a form of design review – the key features being it is a team study, it concentrates on how well the design will cope with abnormal conditions (rather than how well it will perform in normal operation) and it is systematic and detailed.

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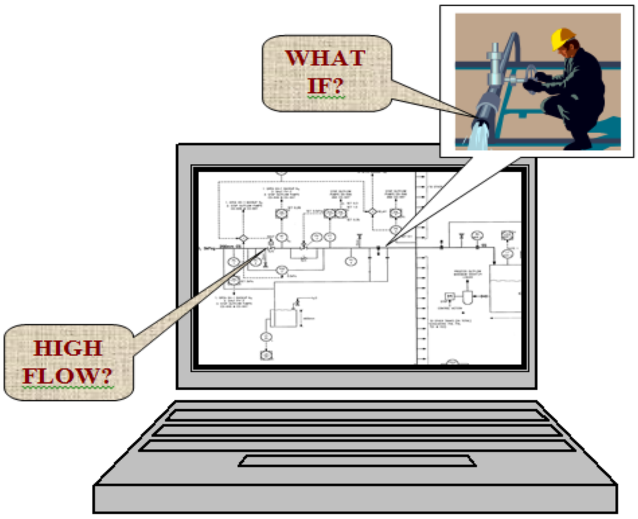
A study considers each process stream or pipeline and vessel examining for each possible cause and consequence of a wide range of process upsets or abnormalities.

It is a very thorough but mainly qualitative approach to 'Failure Mode and Effect Analysis'. When done correctly, the technique is extremely powerful, often highlighting many 'operability' issues not just ignition hazards.



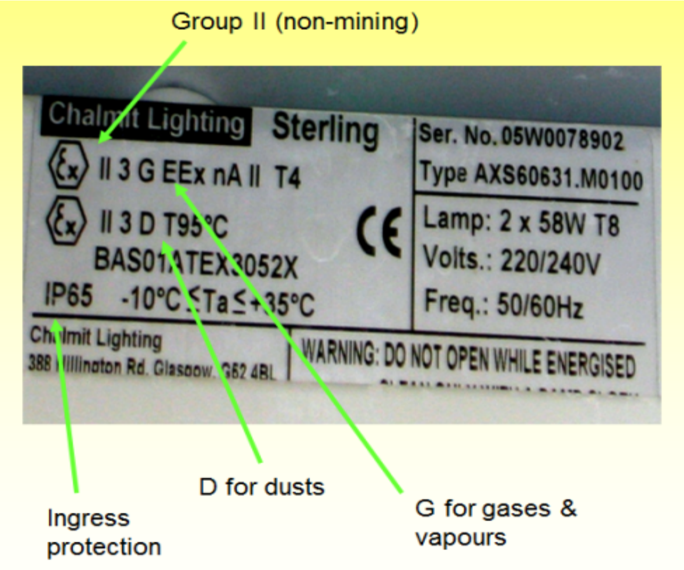
Portable equipment is often brought in to work areas for a specific reason and with good intentions e.g. more heat, more light, etc. However, it is essential that you assess this 'change' i.e. follow your Management of Change Procedures.

Assuming you have some of course!

AND IF NOT, WHY NOT?

The heat lamp may have zero consequences, but there again, it might have been brought in to increase the evaporation rate of solvent wet material – Yes, it happens!

As we've said, electrical and mechanical equipment must be certified for the specific hazardous area AND 'process specific' sources such electrostatic ignition e.g. from solvent or powder transfers, etc.



Predictive Maintenance

Good engineering practices and strict maintenance regimes are vital also. Hopefully, the days of 'if it ain't broke don't fix it' are long gone; and now there is a 'new kid' on the block – **Predictive Maintenance**.

New gadget developed by RAC monitors car to warn of potential mechanical problems

"It can detect battery failure, brake wear or a clogged filter"

What critical items do you have and what is the best means of identifying the predicted fault?

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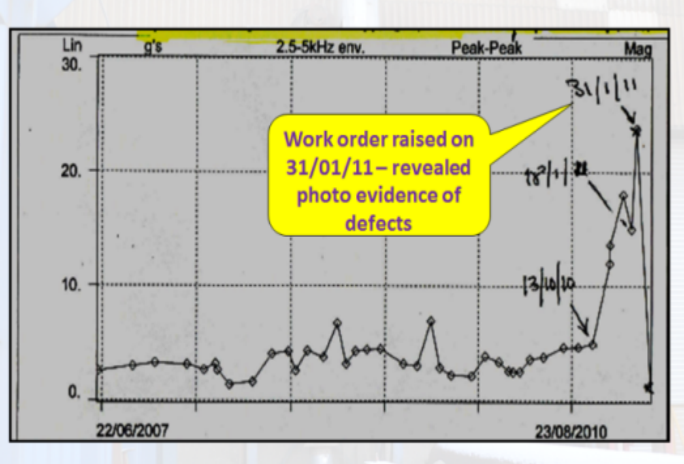
Tech warns of possible breakdown

DRIVERS could have faults in their car diagnosed before they break down, thanks to a new RAC early-warning system.

The matchbox-sized gadget will be launched later this year, and simply plugs into the car's on-board diagnostic socket.

The potential failure of 'process critical' or 'safety critical' items should be monitored since this will help identify problems **BEFORE** they arise – the key benefit being that **YOU** shut down the plant when it's convenient to you rather than having an unscheduled breakdown (which is never convenient).



In the example shown above, Roller Bearing defects were identified early, by vibration monitoring.

This ebook has been developed to help you establish a simple basis of safety in your plant and dispel some of the myths associated with process and safety risk assessments.

We hope you have found the book both informative and helpful. We are here to help you if you require assistance and we look forward to the opportunity of working with you in the future.

Stay safe!

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