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Fire and explosion hazards in the process industries

How conducting appropriate risk assessments can help minimise the risks, by Steve Manchester, Associate Director, BRE Global

Introduction

Industry handles many different types of materials, many of which are combustible. If the materials can form a dust, mist or gas/vapour cloud suspended in the atmosphere then the hazard changes from one of fire to that of an explosion with potentially far greater consequences in terms of life safety and property damage.

Seemingly innocuous materials such as flour, chocolate, rubber, aluminium, and even dried sewage sludge, in the form of a fine dust, can pose a risk from a dust explosion, in particular when being handled in large quantities. Flammable liquids can also pose an explosion risk especially those being used in confined areas and having low flash points. The effects of temperature and pressure also need to be considered as even flammable liquids with high flash points such as hydraulic oils can form explosible mist clouds when leaks are formed in high pressure hoses. Thus it can be seen that the first hurdle to overcome when assessing the risks in the workplace from explosion hazards is to accurately identify the materials involved and, crucially, the conditions under which they are used.

Legislation

There are two pieces of legislation that concern the majority of workplaces when it comes to fire and explosion hazards, the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) and the Regulatory Reform (Fire Safety) Order 2005 (FSO). The cornerstone of both is the need to conduct risk assessments. There are specific aspects that need to be addressed under the two pieces of legislation. This means that a risk assessment conducted to comply with the FSO would most likely not be deemed suitable and sufficient under DSEAR and vice versa.

Dust explosion risk assessment

In the vast majority of cases the user knows that they are handling flammable liquids and gases and the ignition properties of these materials can usually be found in the Material Safety Data Sheets (MSDS) from the manufacturer or obtained from published sources. With dusts however there are far fewer published sources available and the propensity for ignition and severity of the explosion is also dependent on factors such as particle size and moisture content. To assist in assessing if a powder is explosible in the first instance, and then to quantify the explosion parameters, there are standard tests that are used. These tests follow harmonised European standards and include the following tests:

- Dust layer ignition temperature

- Minimum ignition temperature of the dust cloud
- Minimum explosible concentration
- Minimum ignition energy
- Limiting oxygen concentration
- Maximum pressure and rate of pressure rise (Kst)

Minimum Ignition Energy apparatus

Gathering the explosion properties of the materials being handled is an important first step in conducting the risk assessment to comply with DSEAR. By conducting the above tests on your dust samples information may be obtained on how the dust may ignite, e.g. from hot surfaces or static, the concentration required and the severity of an explosion if an ignition of a dust cloud should occur.

Identifying the potential sources of ignition in the work place and within the processes used in the manufacturing or handling of the dust is the next key stage in the risk assessment. Ignition may arise from glowing embers arising from layers of dust on hot surfaces, hot surfaces igniting the dust cloud, electrical and static discharges, or from naked flames. These sources may arise from within the manufacturing process itself, or from electrical or mechanical equipment associated with the process or present in the area of the process.

Once all the flammable materials and the potential sources of ignition have been identified, an evaluation of the likelihood of an ignition is required, along with a judgement of the subsequent severity of such an event. To make such an evaluation the assessor must have a good in-depth knowledge and understanding of the work processes and the fire/explosion behaviour of the materials.

Hazardous area zoning

A technique that is of benefit in assessing the likelihood of an ignition, and which is also a mandatory requirement to comply with DSEAR, is Hazardous Area Zoning. This exercise determines the sources from which a flammable dust or gas cloud may form and how long it could persist. Areas are thus identified and mapped as zones in the work area, both inside the process equipment and external to the equipment usually inside the building but in some cases outside as well. Hazardous zones are allocated as follows:

Gases/vapours:

0 – explosive atmosphere is present continuously or for long periods or frequently.

1 – explosive atmosphere is likely to occur in normal operation occasionally.

2 – explosive atmosphere is not likely to occur in normal operation but, if it does occur will persist for a short period only.

Dusts:

20 – explosive atmosphere is present continuously or for long periods or frequently.

21 – explosive atmosphere is likely to occur in normal operation occasionally.

22 – explosive atmosphere is not likely to occur in normal operation but, if it does occur will persist for a short period only.

In allocating the type and extent of the zone the quantification of the ventilation of the area is a key parameter as well as the behaviour of the material itself. For gases and vapours a standard procedure is described in BS EN 60079-10-1:2009. However, for dusts, although there is also a standard to follow (BS EN 60079-10-2:2009) the zone allocated and the extent for that zone is very much down to the judgement and experience of the assessor, who must determine if the dust cloud likely to be present is of sufficient concentration to be explosible and for how long it will be present. A determination of the Minimum Explosible Concentration of the dust will assist in that it will provide a value of the concentration above which a dust cloud can ignite, typically above $40 g/m^3$.

What is not so easy, particularly for dust clouds external to a process, is to relate this concentration to a visible dust cloud in the building. In assessing the dust zone, layers and deposits must also be taken into account as they can be disturbed to form dust clouds. A judgement will have to be made on how likely and often this may occur, and whether the resulting clouds will form a sufficiently concentrated dust cloud to be ignitable.

Once the zones have been allocated the subsequent report should as a minimum provide schematic diagrams of the process and/or building clearly showing the type and extent of the zones. These are then often transferred to more detailed CAD engineering drawings. Entrances to the zoned areas must be marked wit the Ex triangle.

The likelihood of an explosion can then be evaluated which will form a component part of assessing the risk for each identified hazard.

The next stage is to determine the severity of the explosion should one occur. This will need to take into account life safety and injuries to personnel, damage to infrastructure, business continuity and environmental impact (as demonstrated by the recent explosion of the Deepwater Horizon oil rig in the Gulf of Mexico). By multiplying the likelihood of the event by the severity or consequences of the event, a value of the risk can be obtained. Once the risk has been calculated a judgement will then need to be made on whether the risk can be reduced further or is ALARP (As Low As Reasonably Practicable).

In the process industries there are a number of techniques that can be used to reduce the risks of a dust explosion, however not all are suitable for every process and they need careful evaluation to determine if they are suitable and will be effective if called into use.

Mitigation methods

As with all hazards the primary risk mitigation method is prevention by, for example, substituting flammable materials for non-flammable, ensuring flammable dust or gas clouds do not form or the removal of all ignition sources. In some processes explosion prevention is by oxygen removal by using inert gases such as nitrogen or carbon dioxide. However, in most cases explosion prevention cannot be relied upon as the sole basis of safety, and is usually supplemented by explosion protection. Techniques that can be applied are:

- relief venting
- suppression
- containment

The applicability of these techniques is dependent on the process vessels, the materials being handled and the proximity of the process to safe areas outside the building. For example, explosion relief venting is usually the easiest and most cost effective option, but the vessel must be located close to an outside wall or roof to enable venting into a safe area, as the resultant fire ball and pressure wave can be many metres in length and diameter. If venting inside a building is the only option, due to the layout of the process, then flameless vents are an alternative to consider which extinguish the flame front, though still allowing the explosion pressure to be released.

Thus, by applying explosion prevention and protection methods, there should be scope to further reduce the risks in the risk assessment.

Equipment certification

Equipment that may come into contact with flammable atmospheres must be ATEX certified in accordance with the Equipment and Protective Systems in Potentially Explosive Atmospheres Regulations 1996. The certification of the equipment is directly related to the hazardous zone in which it will be working and is marked with the Ex hexagon.

The equipment is split into two groups: Group I for mines and Group II which covers all other workplaces. These Groups are then further split into the following categories which are directly related to the hazardous area zone:

Category 1: suitable for use in all zones

Category 2: suitable for use in zones 1 and 2, or 21 and 22

Category 3: suitable only for use in zones 2 or 22

Equipment that is suitable for use in both gas and dust flammable atmosphere will be marked with both a ‘G’ and ‘D’ on the equipment. Otherwise only a single letter will be used if the equipment is only suitable for a single type of atmosphere.

Maximum surface temperature information should also be present on the equipment which is important in that hot surfaces can be a source of ignition. For equipment used in gas atmospheres this will be in the form of a ‘T’ rating. There are six categories:

T1	450°C	T4	135°C
T2	300°C	T5	100°C
T3	200°C	T6	85°C

Dust equipment may have the actual temperature shown on the equipment rather than the ‘T’ number.

Once a hazardous area has been designated in a workplace then the correct equipment must be used in that area which is suitable for the allocated zone. This reduces the risk of the equipment being an ignition source for the flammable atmosphere.

There is an alternative risk assessment method encompassing equipment protection levels (EPLs) which were introduced as an alternative approach to the above method of selecting suitable equipment for hazardous areas. Further information on this approach is given in BS EN 60079-10-2:2009.

Bulk storage

An area often overlooked when conducting both DSEAR and FSO risk assessments in industrial processing sites is the risk posed by bulk storage of materials that have the potential to self-heat leading ultimately to spontaneous combustion, i.e. the ignition source is generated within the material itself and is not due to an external source. Bulk storage can use external silos or may be piled on the floor within a building. The risks of a fire from such storage must be included in the DSEAR assessment, as well as the FSO risk assessment, as DSEAR covers self-heating materials.

Materials can be assessed for self-heating by undertaking testing to BS EN 15188:2007. The results of the tests can then be applied directly to process plant using a technique called Thermal Ignition Theory in which safe operating temperatures, volumes and time to ignition can be calculated.

Bulk storage of ammonium nitrate

Conclusions

It is important that the risk assessment is updated when significant changes are made to the materials being handled and/or the process.

The DSEAR risk assessment and hazardous area zoning information must be available for inspection by the HSE, and for the FSO risk assessment, the Fire and Rescue Service.

For the majority of workplaces a separate risk assessment to cover flammable atmospheres and self-heating will be required as the fire risk assessment to meet the FSO will not be suitable and sufficient to cover DSEAR.

Please contact BRE Global for further information on dust explosion and self-heating testing, and for undertaking fire and explosion risk assessments.