

Gas explosions and protective measures

Fundamentals of explosion protection

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Without the need for special expert knowledge, safety experts and those responsible for operation should be able to assess whether their plant is subject to explosion hazards resulting from flammable gases, vapours or mists mixed with air, and should be informed of fundamental protective measures. Below, we shall discuss how an explosive atmosphere can occur, what possible ignition sources must be noted and what measures prevent explosions or reduce their effects to a safe extent.

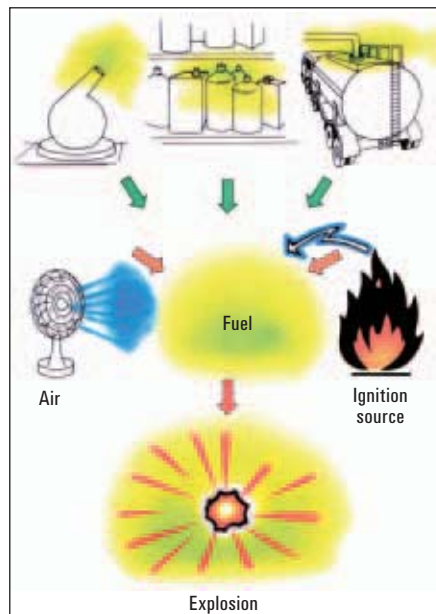


Figure 1: Requirements for the occurrence of explosions

1. Prerequisites for the occurrence of explosions

An explosion hazard can exist in a plant when flammable liquids or flammable gases are produced, stored or handled and, during this process, gases, vapours or mists are released and may form an explosive atmosphere together with air. An explosive atmosphere – a mixture of flammable gas, vapour or mist and air – can occur when working with flammable substances in unenclosed spaces, e.g. when transfusing liquids, as the result of leaks

in the processing equipment or in the event of a malfunction in the operating sequence. Flammable vapours occur from liquids whose temperature lies above the flash point, in which case mists, in turn, may be formed when spraying liquids.

The flash point of a flammable liquid is the lowest temperature at which, under certain conditions, vapor develops from the liquid in sufficient quantity that this immediately ignites upon contact with an effective ignition source.

If the flash point of the liquid lies below the working temperature or processing temperature, there is a risk of explosion.

Even below the flash point, mists of flammable liquids may result in a risk of fire and explosion. So the flash point is an important characteristic parameter of a flammable liquid which can be used to assess whether handling this liquid may result in a risk of explosion.

An explosion is a chemical reaction involving a flammable substance, which takes place very rapidly and during which large amounts of energy are released. A more violent reaction than an explosion occurs in the case of detonation, in which the rate at which the chemical reaction or flames spread through

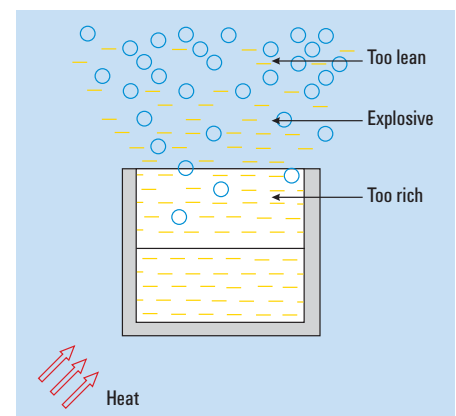


Figure 2: explosion range

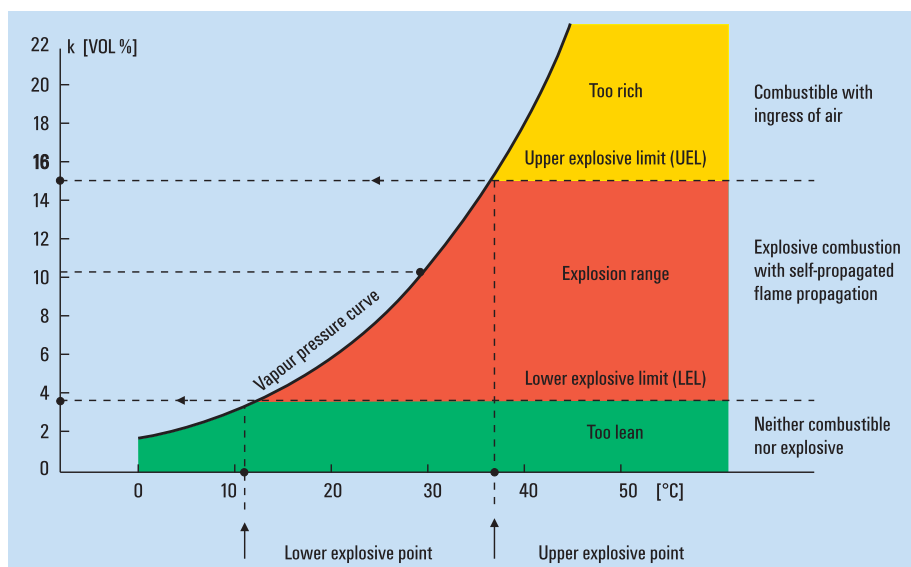


Figure 3: Vapour pressure curve of ethyl alcohol

the reacting mixture accelerates to a speed greater than the velocity of sound. An explosion in a long pipeline may develop into a detonation, for instance, or as the result of barriers to the propagation of the explosion. We speak of an explosive atmosphere if a mixture of flammable gases, vapours or mists in air is present in such quantities – within the explosion limits – that an explosion occurs after ignition.

An explosion may occur if the following conditions apply simultaneously (Figure 1):

- flammable gases, vapours or mists in a mixture with air within the explosive limits, i.e.
 - a) sufficient fuel content and
 - b) sufficient oxygen content (adequately present in air!)
- an effective ignition source

An explosion can be prevented by guaranteed avoidance of one of these conditions. Flammable gases, vapours or mists are explosive when mixed with air only within a certain range of concentration (Figures 2 and 3). Too little flammable substance is present below the lower explosion limit (LEL): the mixture is too lean.

Too much flammable substance is present above the upper explosion limit (UEL): the mixture is too rich. The region of concentration between the lower and upper explosion

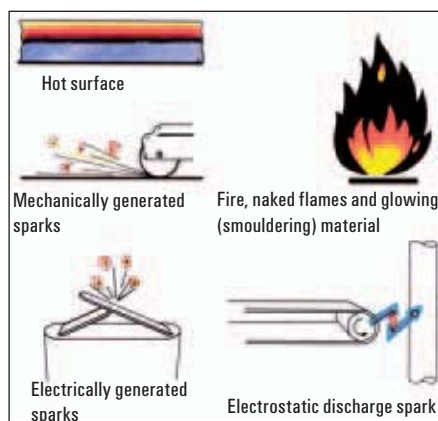


Figure 4: Possible ignition sources

limits is the explosion range. Within this range of concentration a mixture is explosive, i.e. an explosion hazard exists.

The explosion limits are specified as vol % or in g/m³. Values of the explosion limits depend on the particular substance and are determined experimentally.

The normal oxygen content in air must be considered as sufficient for an explosion.

Flammable gases, vapours or mists are, however, still explosive even at reduced oxygen contents. More violent explosions occur when the oxygen content is greater than that of air.

An explosive atmosphere becomes a hazard only, if it coincides with an effective ignition source. A variety of ignition sources occur in the industrial practice. The most important

sources are as follows (Figure 4):

- Hot surfaces, e.g. of electrical equipment,
- Fire, naked flames and glowing material,
- mechanically generated sparks and arcs,
- electrically generated sparks,
- electrostatic discharge sparks.

Not every ignition source contains sufficient energy to ignite all types of explosive mixtures. An ignition source is effective, if it can supply enough energy to the explosive atmosphere to cause initiation of a self-sustaining propagation of combustion reaction.

2. Protective measures

If, after considerations of the risks, an explosion hazard is thought to exist, one or more of the following measures must be taken:

- avoidance or restriction of the formation of an explosive atmosphere,
- avoidance of effective ignition sources,
- avoidance of hazardous effects of an explosion.

While the two first measures are intended to exclude the possibility of an explosion occurring, the third measure is intended to reduce the effect of an explosion that has occurred to a harmless extent. A combination of these options may be practical or required and the technical measures should always be accompanied by organisational measures.

In the case of flammable gases, vapours and mists, avoiding the formation of an explosive atmosphere has priority over avoiding ignition sources and measures of 'constructional explosion protection measures'.

Preventing the occurrence of an explosion

There are measures that prevent explosions either by keeping the concentration of the flammable substance so low that the fuel/air mixture is too lean for an explosion, or by excluding the possibility of the required oxygen for explosive combustion of the mixture, that is, maintaining the oxygen concentration →

- below the limiting oxygen concentration. The other option is to reliably exclude effective ignition sources.

Limiting the explosive atmosphere

Limitation of the quantity or distribution of the explosive atmosphere can be achieved by the following measures for instance:

- closed systems (leak-tight construction),
- automatic shut-off devices,
- concentration limiting (ventilation measures),
- concentration monitoring (gas detectors units),
- reliably maintaining the working temperature at a value below the flash point.

In the case of ventilation, a distinction is made between forced ventilation and natural ventilation, the latter generally sufficing only in open air. Forced ventilation allows the circulation of greater quantities of air and control over the air flow (e.g. avoidance of unventilated spaces). The relative density-specific gravity of the gases or vapours has an influence on ventilation and this must be taken into account.

The relative density of the vapours of flammable liquids is always higher than that of air.

The same applies to gases, with the exception of acetylene, ammonia, cyanide, ethylene, carbon monoxide, methane and hydrogen.

In the case of gases that are heavier than air and in the case of vapours, the exhaust vents must be arranged near to the ground. In the case of gases that are lighter than air, they must be arranged near to the ceiling. It must be noted that heavy gases and vapours flow into recesses in the ground or floor in the same manner as a liquid and can thus propagate in an uncontrolled manner.

Gas alarm units have the task of monitoring areas in which an explosive atmosphere may occur under specific operating conditions. The use of gas alarm units can, for example, enable protective measures to be automatically triggered, or plant shut down, in an emergency.

However, gas alarm systems must be suitable specifically for the scheduled intended application and must be inspected for operability at stipulated maintenance intervals.

One other option is to limit the oxygen concentration by 'inerting', i.e. the oxygen is displaced by non-flammable gases such as nitrogen or carbon dioxide to such an extent that the actual oxygen concentration falls below the limiting oxygen concentration, thus an ignition can not take place. This measure is extremely reliable, but mostly applicable only in closed plant units. It requires high equipment complexity, must be monitored by measuring systems and incurs high operational costs owing to consumption of the inert gas as a function of size and leak-tightness of the installation (Figure 5).

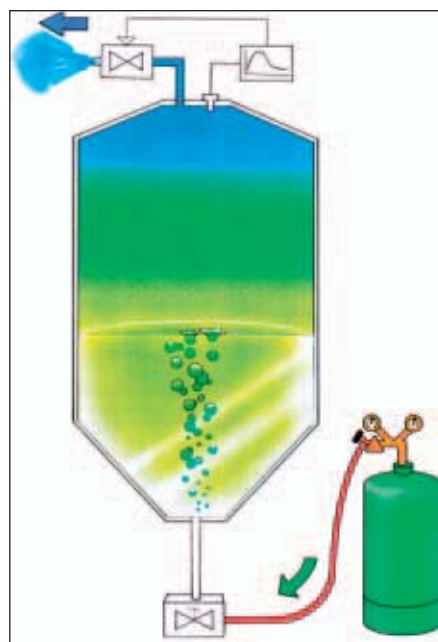


Figure 5: Inerting by non-flammable gases

Zone classification of hazardous installations

Areas in which there is an explosion hazard are divided into zones depending on how frequently and for how long an explosive atmosphere can occur or can be present.

■ Zone 0

A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour

or mist is present continuously or for long periods or frequently.

■ Zone 1

A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.

■ Zone 2

A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

The degree of the measures required will differ in extent in accordance with the zone classification of the hazardous areas in order to reliably prevent ignition of the explosive atmosphere.

Avoidance of ignition sources

Elimination of effective ignition sources should always be employed even when constructional protection measures are applied, unless it is possible to reliably exclude the possibility of an explosive atmosphere. Effective ignition sources must be avoided where explosive atmospheres are present or can occur.

Only equipment ensuring a very high level of protection and which even in the event of rare incidents do not cause an ignition, may be used in Zone 0.

For this reason, the equipment is characterized by means of protection such that:

- either, in the event of failure of one means of protection, at least an independent second means provides the necessary level of protection,
- the same necessary level of protection is to be ensured in the event of two faults occurring independently of each other.

In Zone 1, only equipment may be used which ensures the required level of protection, even in the event of frequently occurring disturbances or faults which normally have to be taken into account.

Equipment which ensures a normal level of protection and whose design is such that no ignition source is produced in normal operation (within the limits specified by the manufacturer) may be used in Zone 2.

Unless special precautions are taken, electrical equipment is considered as a potential ignition source. In this case, effective ignition sources include hot surfaces which may come into contact with the explosive atmosphere, →



Figure 6: Explosion protected light fittings for use in Zones 1 and 2



Figures 7: Explosion protected panel-mounting devices for use in Zones 1 and 2



Figure 8: Remote I/O system with intrinsically safe outputs in Zones 0, 1 and 2

→ electrical switching sparks and arcs.

However, ignition as the result of such devices is prevented by special design of this equipment. This is achieved by

- prevention of the coincidence of explosive atmosphere and ignition source,
- limitation of the energy to a non-ignitable value,
- limitation of the effect of a possible explosion inside a piece of equipment to its enclosure.

The various types of protection are conceived on the basis of these principal requirements. These types of protection are standardised in detail in the apparatus Standards EN 50014 Series on European level and internationally in the Standards IEC 60079 Series.

Switchgear devices, light fittings and motors are mainly designed with types of protection Flameproof enclosures ,d' or Increased safety ,e', generally with a combination of both. In the case of type of protection Intrinsic safety ,i', the energy of a circuit is limited so that ignition of an explosive atmosphere is not possible, even in the event of a fault. This type of protection is predestined for use in control and instrumentation systems and this is the sector in which it is mainly used. Type of protection Pressurised apparatus ,p' is one possible design for switchgear installations and analysis equipment in which a protective

gas inside the enclosure prevents an ignition of explosive gas/air mixtures by inerting. This can be achieved by building up an internal overpressure with respect to the surrounding atmosphere to compensate the leakage or by a continuous flow of the protective gas. Figures 6 to 8 show a variety of explosion protected equipment for use in Zones 0, 1 and 2.

Avoidance of the hazardous effects of an explosion

If an explosion cannot be excluded with certainty, constructional explosion measures which avoid the hazardous effects of an explosion must be taken.

Vessels and pipes are constructed or equipped to prevent injury to persons as the result of an explosion and to minimise or prevent damage to buildings or installations.

Measures of constructional explosion protection in tank and vessel construction include explosion-resistant construction, explosion venting or explosion suppression and explosion isolation (Figure 9). Explosion-resistant vessels and installations, including connections of the pipes, valves and fittings etc., must withstand the pressure stress of an explosion with no result in permanent deformation (explosion- pressure resistant) or, if the vessel has been deformed by an explosion, its bursting must be prevented (explosion-pressure-shock resistant). For the purpose of

explosion venting, a vessel to be protected is provided with a venting device that opens at a defined pressure (which must be considerably below the strength of vessel). Facilities for this include, for instance, bursting discs or explosion doors. Pressure venting equipment must always vent into the ,safe direction', i.e. it must never vent into the working place. An explosion suppression system detects an incipient explosion by means of flame or pressure detectors and suppresses the explosion in its incipient phase by rapid injection of extinguishing agents.

If plant units, in particular tanks or vessels, threatened by explosion are connected by pipes, such equipment must generally be isolated from the explosion by suitable devices. This measure can limit the area affected by an explosion. In pipes and vessels the main items used are explosion arresters, flame arresters and detonation arresters.

Organisational measures

Complementary to the preventive and constructional explosion protection measures, it is also necessary to take organisational measures in order to reduce the risk of fire and explosion on one hand and to ensure effectiveness of the technical measures longterm on the other.

Thus, the user instructions must stipulate the behaviour of employees both during normal operation and in the case of malfunctions. Responsibility for the implementation of the measures must be clearly specified. At regular intervals, employees must be informed on possible hazards and their attention drawn to the proper behavior during such incidents.

It must be ensured that the installation is subjected to regular inspection and maintenance, particularly the safety devices such as flame traps, sensors and any equipment/plant sections, which could become ignition sources.

In practice, introduction of a ,Safety Maintenance Check Program' (checklist) has more than proved its worth.

The required personnel protective clothing

and equipment, e.g. in the form of conductive shoes must be provided, used and must be maintained in serviceable condition.

An issue procedure (fire, welding and entry permit) must be introduced for special work, such as welding, grinding and repairing electrical equipment in hazardous areas.

Hazardous areas, such as the area surrounding charge and discharge openings, filling units, pumps and slide valves, must be marked and cordoned off if necessary. This also applies to areas where there is a hazard due to explosion venting (owing to the effects of pressure or flames) or as the result of using inert gases (risk of suffocation).

Structural measures

Structural measures are able to limit the hazards as the result of explosions owing to flammable gases, vapours or mists on one hand and reduce their effects on the building on the other.

Structural measures in particular can also substantially improve safety.

Examples of structural measures to increase safety are as follows:

- fire compartments,
- sealing openings for cables, pipes and vessels etc. emerging from hazardous areas so as to prevent the propagation of gases and flammable liquids or their vapours,
- isolating gullies (e.g. for floor drainage) in hazardous areas by means of installing

siphons,

- Separation of endangered plant units – e.g. filling stations for flammable liquids, pump rooms for flammable liquids, compressor stations – from storage areas,
- Explosion isolation of rooms and areas to prevent the propagation of explosions.

3. Safety parameters

Application of the above mentioned safety measures requires a knowledge of explosion parameters of the flammable gases or liquids used.

If mixtures of flammable liquids are present, the flammability and explosion characteristics of the individual components cannot be taken as a basis alone for assessment of the explosion hazard.

In this connection, one aspect of special importance relates to the low-boiling admixtures that, for instance, reduce the flash point and the lower explosion limit.

Consequently, interpretation and application of safety parameters must be left to experts.

4. Concluding remarks

This article is intended to provide the reader with the basic knowledge to be able to assess whether explosion hazards may occur as the result of flammable gases, vapours or mists when mixed with air, without the reader having to access specialist knowledge in the sector of explosion protection. This article is not intended for elaborating a risk analysis or for answering the question as to whether protective measures are required and possible. Experts must be consulted for this.

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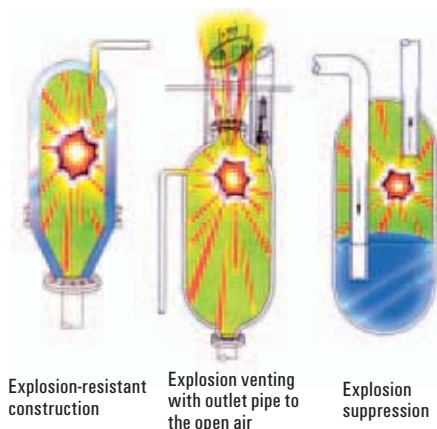


Figure 9: Examples of constructional explosion protection measures

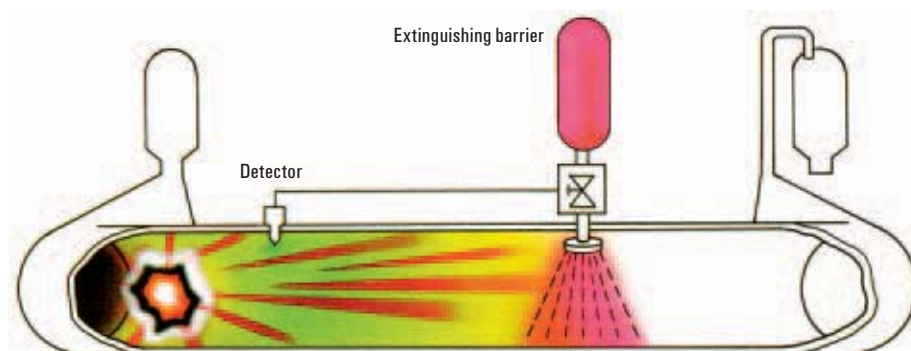


Figure 10: Explosion isolation by extinguishing barrier