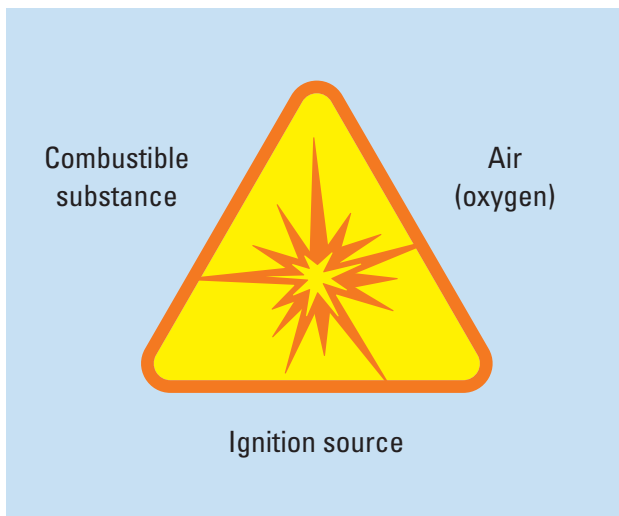


# 1. PHYSICAL PRINCIPLES AND DEFINITIONS

Explosion protection is a key area of safety engineering. So it is essential to understand the fundamental principles of an explosion and its causation factors. The first chapter of our brochure familiarises readers with the main principles and terms in the field of explosion protection.

An explosion is the sudden chemical reaction of a combustible substance with oxygen, resulting in the release of a high amount of energy. An explosion can only occur when three factors are present at the same time (see Fig. 1):

1. Combustible substance.
2. Oxygen (air).
3. Ignition source.



**Figure 1:** An explosion can only occur when these three factors coincide.

## Combustible substance

Combustible substances may be present in the form of gases, mists, vapours or dusts. Safety-relevant parameters need to be considered to characterise hazard potentials.

## Explosive atmosphere

Explosive atmospheres contain a mixture of air and combustible gases, vapours, mists or dust in atmospheric conditions in which after ignition the combustion process spreads to the entire unburned mixture. In general, the atmospheric conditions are deemed to be ambient temperatures of  $-20\text{ °C}$  to  $+60\text{ °C}$ , a pressure range of 0.8 bar to 1.1 bar and an oxygen content of 21% in the air.

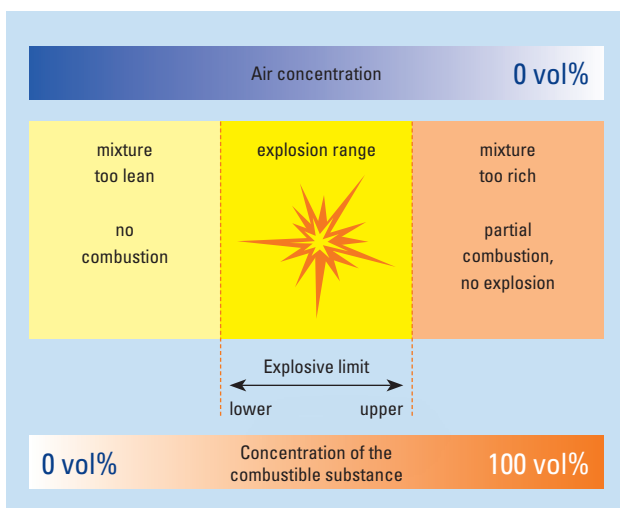
## Flashpoint

The flashpoint is the minimum temperature at which a combustible liquid forms an ignitable mixture with air above the surface of the liquid (in normal air pressure conditions). If the flashpoint of a combustible liquid is far higher than the maximum temperatures which arise, an explosive atmosphere cannot be formed. However, the flashpoint of a mixture of various liquids may be lower than that of the individual components. In the German Ordinance on Hazardous Substances (Gefahrenstoffverordnung), besides its boiling point, the flashpoint of a liquid is used to classify liquids (see Table 1).

**Table 1:** Criteria for combustible liquids

Category	Criteria
1	Flashpoint $< 23\text{ °C}$ and boiling point $\leq 35\text{ °C}$
2	Flashpoint $< 23\text{ °C}$ and boiling point $> 35\text{ °C}$
3	Flashpoint $\geq 23\text{ °C}$ and $\leq 60\text{ °C}$ <sup>(1)</sup>

<sup>(1)</sup> For the purpose of the CLP Regulation, gas oil, diesel and light heating fuels, which have a flashpoint ranging from  $55\text{ °C}$  to  $75\text{ °C}$ , may be deemed to belong to Category 3.



**Figure 2:** Explosive limits

**Table 2:** Explosive limits of specified gases and vapours

Designation of substances	Lower explosive limit [vol. %]	Upper explosive limit [vol. %]
Acetylene	2.3	100 (self-decomposing)
Ethylene	2.4	32.6
Petrol	~0.6	~8.0
Benzene	1.2	8.0
Fuel oil / diesel	~0.6	~6.5
Methane	4.4	17.0
Propane	1.7	10.8
Carbon disulphide	0.6	60.0
Hydrogen	4.0	77.0

Extract from the table "Safety characteristics, Vol. 1: Combustible liquids and gases" by E. Brandes and W. Möller, K. Nabert and G. Schön (6th edition).

## Explosive limits

To form an explosive atmosphere, the combustible substance must be present in a certain concentration (see Fig. 2). In the case of insufficient concentrations (lean mixture) or excessive concentrations (rich mixture) no explosion takes place, but a stationary or non-combustive reaction. It is only in the range between the lower (LEL) and upper (UEL) explosive limits that the mixture reacts explosively when ignited. The explosive limits depend on the ambient pressure and the percentage of oxygen in the air (see Table 2).

## Ignition sources

In order to prevent ignition of a hazardous explosive atmosphere, all potential sources of ignitions must be identified and safeguarded to make them nonthreatening. Ignition of an explosive atmosphere may, for instance, be caused by the following sources:

- Hot surfaces
- Flames and hot gases
- Mechanically generated sparks
- Electrical systems
- Electrical equalising currents, cathodic corrosion protection
- Static electricity
- Lightning
- Electromagnetic waves (high frequency)
- Optical radiation
- Ionising radiation
- Ultrasound
- Adiabatic compression and shock waves
- Exothermal reactions

# 1. PHYSICAL PRINCIPLES AND DEFINITIONS

## Minimum ignition energy

The supply of a specific amount of energy is required to ignite a potentially explosive atmosphere. Minimum ignition energy is the term applied to the minimum amount of energy, for instance when discharging a capacitor, which is just sufficient to ignite the respective combustible mixture. The minimum ignition energy is in the area of  $10^{-5}$  joules for hydrogen and up to a few joules for certain dusts.

## Integrated explosion protection

The principle of integrated explosion protection requires that all explosion protection measures be performed in a fixed order, with a distinction between primary, secondary and tertiary (constructional) protection measures.

## Primary explosion protection

Primary explosion protection covers all measures that prevent the occurrence of a hazardous explosive atmosphere – for prevention is always better than protection. These precautions should therefore always be implemented first. The following protection measures can be adopted:

- avoidance of combustible substances (alternative technologies).
- inerting (addition of nitrogen, carbon dioxide, etc.).
- limiting of the concentration by means of natural or artificial ventilation.

## Secondary explosion protection

If explosion hazards cannot be entirely or only partially excluded by measures to prevent the formation of explosive atmospheres, measures must be adopted to prevent the ignition of explosive atmospheres. The required safety level of these measures depends on the hazard potential at the operating location.

## Tertiary or constructional explosion protection

If the occurrence of a hazardous explosive atmosphere cannot be safely prevented and its ignition cannot be excluded, measures must be adopted that limit the impact of an explosion to a negligible extent. The following precautions are possible:

- flameproof or pressure-surge-resistant design.
- pressure relief and pressure compensation equipment.
- explosion suppression with extinguishing devices.

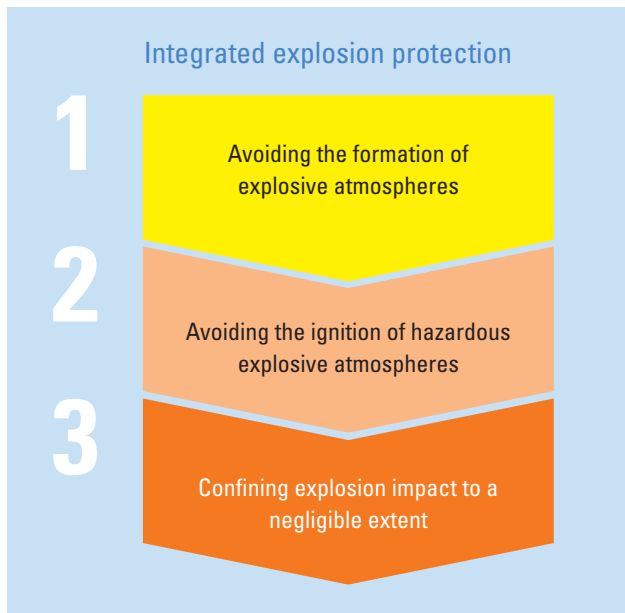


Figure 3: Explosion protection measures