POCKET GUIDE

Basics
explosion protection

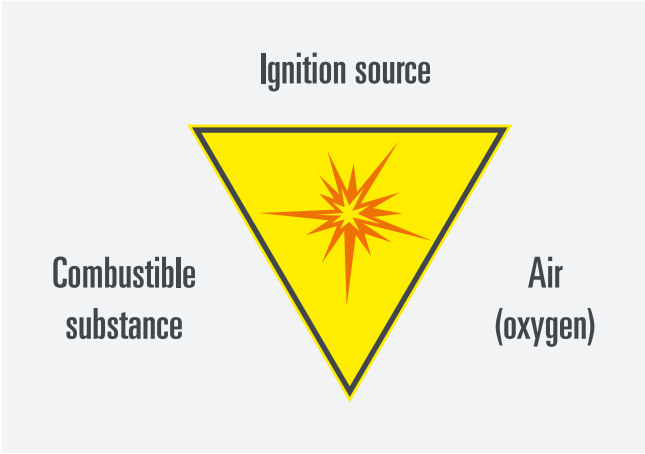
STAHL

Contents

Physical basics and definition

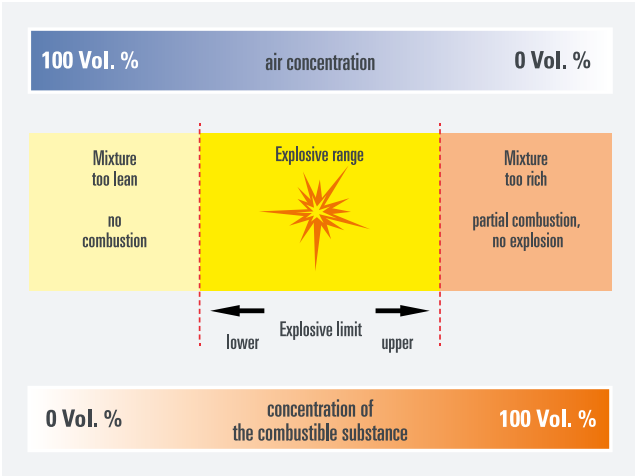
An explosion is the sudden chemical reaction of a combustible substance with oxygen, with the release of a high amount of energy.

Combustible substances may be present in the form of gases, vapours, mists or dusts. An explosion can only occur when three factors are present at the same time:



Certain characteristic properties of these substances have to be observed for safety considerations. The flash point is the lowest temperature of a combustible liquid at which a flammable vapour-air-mixture builds up above the liquid level (with normal air pressure). If the flash point of a combustible liquid is significantly higher than the maximum temperatures, an explosive atmosphere cannot build up.

In order to form a potentially explosive atmosphere, the combustible substance has to be present in a certain concentration.



If the concentration is too high (rich mixture), or too low (lean mixture), no explosion will occur, only local combustion, or no combustion reaction at all. Only in the range between the upper and lower explosion limit will the mixture react explosively when it is ignited. The explosive limits depend on the ambient pressure and the proportion of oxygen in the air.

Table 1: Explosive limits of specified gases and vapours

Substance designation	lower explosive limit [Vol. %]	upper explosive limit [Vol. %]
Acetylene	2.3	100 (self-decomposition)
Ethylene	2.4	32.6
Petrol	~ 0.6	~ 8
Benzene	1.2	8
Fuel oil/diesel	~ 0.6	~ 6.5
Methane	4.4	17
Propane	1.7	10.8
Carbon disulphide	0.6	60.0
Hydrogen	4.0	77.0

Table 2: Classification of flammable liquids

Designation of the flammable liquid	flash point and boiling point °C
extremely flammable	flash point < 23 °C and boiling point ≤ 35 °C
highly flammable	flash point < 23 °C and boiling point > 35 °C
flammable	23 °C ≤ flash point ≤ 60 °C

Legal provisions

The International Electrotechnical Commission (IEC) is responsible for the global standards for electrical engineering.

IEC standards that are concerned with the explosion protection of electrical equipment and facilities are developed by the Technical Committee TC31 and are similar to recommendations which largely all standards are oriented to. Until a few years ago, requirements for gas explosion hazardous areas were defined in standard series 60079, and for areas with combustible dust, the requirements were defined in series 61241. As a lot of requirements are similar for both areas, both standard series have been combined in series IEC 60079.

In Europe, these standards are published in series EN 60079.

For non-electrical equipment, standard series EN 13463 has been prepared in Europe. Currently, these standards are discussed on an international level and they will be published as standard series ISO/IEC 80079.

In Europe, first and foremost the European directives are applicable: Directive 94/9/EC has recently been replaced by directive 2014/34/EU (also called ATEX directive) and defines the basic requirements in regard to explosion-protected equipment.

Directive 1999/92/EC governs the operation in potentially explosive areas and defines measures to ensure the safety of the employees.

Certification

There are different accredited IECEx certification bodies all over the world (ExCB = certification body) and accredited IECEx test laboratories (ExTLs) that are accredited pursuant to high uniform criteria and that are regularly monitored.

At IECEx, a certificate will only be granted when the type test of the test samples has been passed, and the existence of an effective quality management system has been proven by an audit.

Currently, there are own regional and national approval processes all over the world, like, for example, the ATEX directive in the European Union or national approvals in the USA (UL, FM).

Explosion protection measures

Primary explosion protection

The term primary explosion protection refers to all precautions which prevent the formation of a dangerous explosive atmosphere.
This can be achieved by:

- avoiding combustible substances (different technologies)
- inerting (addition of nitrogen, carbon dioxide, etc.)
- limiting of the concentration by means of natural or technical ventilation

Ignition prevention of potentially explosive atmospheres

The required safety level of these measures depends on the possible hazard potential at the installation location. Hazardous areas are therefore divided into Zones according to the probability of an explosive atmosphere being present.

Table 3: Potentially explosive atmosphere

Substance designation	IEC	EN
Equipment – general requirements	IEC 60079-0	EN 60079-0
Equipment protection with flameproof enclosure »d«	IEC 60079-1	EN 60079-1
Classification of areas – explosive gas atmospheres	IEC 60079-10-1	EN 60079-10-1
Classification of areas – combustible dust atmospheres	IEC 60079-10-2	EN 60079-10-2
Equipment protection by intrinsic safety »i«	IEC 60079-11	EN 60079-11
Equipment protection by pressurized room	IEC 60079-13	EN 60079-13
Project engineering, selection and installation of electrical installations	IEC 60079-14	EN 60079-14
Electrical equipment in type of protection »n«	IEC 60079-15	EN 60079-15
Artificial ventilation for the protection of analysis rooms	IEC/TR 60079-16	

Inspection and maintenance of electrical installations	IEC 60079-17	EN 60079-17
Equipment protection by encapsulation	IEC 60079-18	EN 60079-18
Equipment repair, overhaul and reclamation	IEC 60079-19	EN 60079-19
Equipment protection by pressurized enclosure »p«	IEC 60079-2	EN 60079-2
Material characteristics for classification of gases and vapours – test methods and data	IEC 60079-20-1	EN 60079-20-1
Intrinsically safe systems	IEC 60079-25	EN 60079-25
Equipment with equipment protection level (EPA) Ga	IEC 60079-26	EN 60079-26
Protection of equipment and transmission systems using optical radiation	IEC 60079-28	EN 60079-28
Gas detectors – performance requirements of detectors for flammable gases	IEC 60079-29-1	EN 60079-29-1
Gas detectors – Selection, installation, use and maintenance of detectors for flammable gases and oxygen	IEC 60079-29-2	
Gas detectors – open path detectors for flammable gases: general and testing requirements	IEC 60079-29-4	EN 61241-1
Electrical resistance trace heating – General and testing requirements	IEC 60079-30-1	EN 60079-30-1

Electrical resistance trace heating – application guide for design, installation and maintenance	IEC 60079-30-2	EN 60079-30-2
Equipment dust ignition protection by enclosure »t«	IEC 60079-31	EN 60079-31
Electrostatic hazards	IEC/TS 60079-32-1	
Equipment protection by special protection »s«	IEC 60079-33	
Method of test for ignition temperature	IEC 60079-4	
Equipment protection by powder filling »q«	IEC 60079-5	EN 60079-5
Equipment protection by oil immersion »o«	IEC 60079-6	EN 60079-6
Equipment protection by increased safety »e«	IEC 60079-7	EN 60079-7
Type of protection »pD«	IEC 61241-4	EN 61241-4
Test methods: minimum ignition temperature	IEC 61241-2-1	EN 50281-2-1
Test methods: resistivity of dust in layers	IEC 61241-2-2	EN 61241-2-2
Test methods: minimum ignition energy (IEC 60079-20-2-draft)	IEC 61241-2-3	
Safety devices required for the safe functioning of equipment with respect to explosion risks		EN 50495

Limiting the effects of an explosion
(Constructive explosion protection)

When the development of hazardous, potentially explosive atmosphere cannot be safely prevented, and in case ignition cannot be excluded, measures have to be taken that limit the effects of an explosion to non-hazardous proportions, e.g., in case of containers and silos, with:

- an explosion-resistant or explosion pressure shock-resistant construction
- pressure relief equipment and pressure compensation equipment
- explosion suppression with extinguishing devices
- avoidance of explosion propagation to other areas

Ignition sources

Ignition of a potentially explosive atmosphere can be caused by various ignition sources:

- hot surfaces
- flames and hot gases
- mechanically generated sparks
- electrical installations
- electrical equalizing currents, cathodic corrosion protection
- static electricity
- lightning
- electromagnetic waves (high frequency)
- optical radiation
- ionizing radiation
- ultrasound
- adiabatic compression and shock waves
- exothermic reactions

Ignition sources have to be avoided in hazardous areas.

Classification of Zones – equipment categories and equipment protection level (EPL)

With respect to the ignition sources, hazardous areas are classified into Zones to facilitate the selection of adequate equipment and the design of appropriate electrical installations. Zone classification reflects the probability of a potentially explosive atmosphere developing.

The maximum risk potential has to be taken into account when dividing the potentially explosive areas into zones and determining the necessary protective measures. The equipment used in the defined hazardous zone must meet the requirements of the relevant assigned equipment category or equipment protection level.

Table 4: Zone classification

Gas	**Zone 0**	area in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas or vapour is present continuously or for long periods or frequently
	Zone 1	area in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas or vapour is likely to occur in normal operation occasionally
	Zone 2	area in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas or vapour is not likely to occur in normal operation but, if it does occur, will persist for a short period only
Dust	**Zone 20**	area in which an explosive atmosphere in the form of a cloud of dust in air is present continuously, or for long periods or frequently
	Zone 21	area in which an explosive atmosphere in the form of a cloud of dust in air is likely to occur, occasionally, in normal operation
	Zone 22	area in which an explosive atmosphere in the form of a cloud of dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only

Table 5

Equipment category pursuant to directive 94/9/EC	Equipment protection level (EPL) pursuant to IEC 60079-0	Protection level	Zone
1G	Ga	very high	0
2G	Gb	high	1
3G	Gc	normal/increased	2
1D	Da	very high	20
2D	Db	high	21
3D	Dc	normal/increased	22

7 Types of protection

Electrical explosion-protected equipment for gas and dust hazardous areas can be designed in different types of protection, pursuant to the building regulations given in standard series IEC 60079 or EN 60079. Types of protection for non-electrical equipment are defined in standard series EN 13463.

The type of protection a manufacturer applies to a device mainly depends on the type and function of the equipment. For some types of protection there are different protection levels. These correspond to the equipment categories pursuant to guideline 94/9/EC, or the equipment protection levels (EPL) pursuant to IEC 60079-0 dated 2007.

For example, in case of intrinsic safety, there is version Ex ia, which is classified in category 1G or EPL Ga. It can be installed in Zone 0. Version Ex ib corresponds to category 2G or EPL Gb, which is suitable for Zone 1 and Ex ic, category 3G or EPL Gc, can be applied in Zone 2.

In regard to safety, all standardized types of protection within a category or an equipment protection level can be regarded as being equivalent.

Marking

Marking of electrical equipment is defined in IEC 60079-0. In addition to the name of the manufacturer or his trademark, the type designation, the serial number and the certification body with certificate number, a special coding is required that describes the use of the equipment:

- Symbol Ex
- The symbol of each type of protection that has been applied, e.g. Ex d e
- Group IIA, IIB, IIC respectively IIIA, IIIB, IIIC
- Temperature class in case of devices for explosive gas atmospheres, or maximum surface temperature of the devices for explosive dust atmospheres
- Equipment protection level EPL:
  - Ga, Gb, Gc for explosive gas atmospheres
  - Da, Db, Dc for explosive dust atmospheres

On the associated equipment that must not be installed in potentially explosive areas, the symbols showing the type of protection have to be given in square brackets.

In Europe, additional marking is required by directive 94/9/EC (ATEX):

- Symbol Ex
- Group I (for mining), or group II for other sectors than mining
- Category 1, 2 or 3 with the additional letter G (Gas) or D (dust), e.g. Ex II 2G
- The CE mark

Table 6: Gases are classified into groups according to their ignition characteristics

Group	Typical gas	Hazardousness of the gases
IIA	Propane	+
IIB	Ethylene	++
IIC	Hydrogen	+++

Table 7: Dusts are classified into the following groups

Group	Dust	Hazardousness of the dusts
IIIA	combustible lint	+
IIIB	non-conductive dust	++
IIIC	conductive dust	+++

Table 8: Temperature classes

Ignition temperature of gases and vapours in °C	Temperature class	Maximum surface temperature on equipment in °C
> 450	T1	450
> 300 up to 450	T2	300
> 200 up to 300	T3	200
> 135 up to 200	T4	135
> 100 up to 135	T5	100
> 85 up to 100	T6	85

Installation and operation of electrical equipment

The plant operator is responsible for the safe operation of the facility. He has to assess the explosion hazard and classify the Zones accordingly. He has to ensure that the facility is properly installed and tested prior to operation.

The proper state of the facility has to be kept with regular inspections and maintenance. The requirements regarding operation of facilities in hazardous areas are defined in the national regulations.

In Europe, the minimum requirements are defined in directive 1999/92 EC. The specific requirements in the different countries are defined in the national regulations.

Different standards have been prepared on an international and on a European level.

The installer has to observe the installation requirements and select and install the electrical equipment correctly according to their intended use.

Table 9: Potentially explosive atmosphere (gas and combustible dust)

	IEC	EN
Electrical installations design, selection and erection	IEC 60079-14	EN 60079-14
Electrical installations inspection and maintenance	IEC 60079-17	EN 60079-17
Equipment repair, overhaul and reclamation	IEC 60079-19	EN 60079-19

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