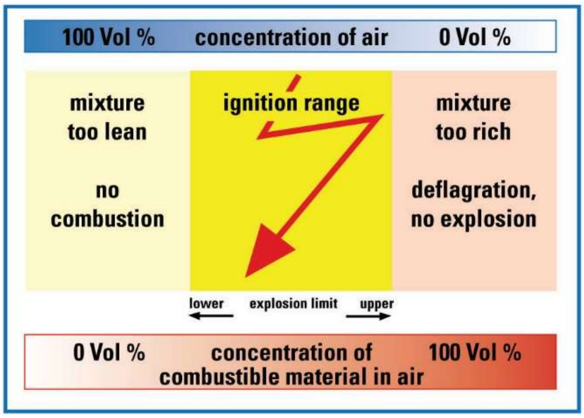
Explosion Safety.

Introduction

An explosion is caused by a sudden chemical reaction of a combustible substance with oxygen that releases a large amount of energy. Flammable substances can be solid, gaseous, vaporous or misty. For an explosion to occur, the following three factors must be present:

1. A combustible substance (at the appropriate concentration).
2. Oxygen (from the air).
3. An ignition source.

The flash point of a substance is an important material property in an explosion. The flash point of a flammable liquid is the minimum temperature at which vapor of sufficiently high concentration is released to form a flammable mixture with the oxygen in the air (at atmospheric pressure). If the flash point of a flammable liquid is well above the maximum achievable temperature, an explosive mixture will not form. The flash point of a mixture of liquids may be lower than that of the individual components.To form an explosive atmosphere, the flammable material must be present in a certain concentration.



- Figure 1 Lower and upper explosion limits of a flammable material.

At too low a concentration and at too high a concentration of the flammable material, no explosion occurs, only a slow reaction or even no reaction at all may occur. Only between the lower and upper explosion limits can an explosion occur. The explosion limits depend on the air pressure and oxygen concentration in the air.

To ignite an explosive atmosphere, supply of a minimum amount of energy by an ignition source is required. The following ignition sources are possible:

- Hot surfaces
- Electric sparks
- Electrostatic discharge
- Mechanical friction involving the release of heat and/or sparks.
- Electromagnetic radiation
- Shock waves

- Ionizing radiation
- Optical radiation
- Chemical reactions
- Open flames.

Primary explosion protection:

This can be achieved by taking measures so that ignition of an explosive atmosphere is prevented. The following measures can be taken:

- Ensure that no flammable substances are present
- Supply inert medium such as nitrogen or carbon dioxide
- Limit the concentration of combustible dust
- Apply natural or forced ventilation.

Secondary explosion protection:

If primary explosion protection does not or partially eliminate the explosion hazard, measures must be taken that prevent ignition of the explosive atmosphere. To this end, hazardous areas are divided into zones according to the probability that the explosive atmosphere may occur. In the USA, among others, these zones are classified into Classes and Divisions. Devices that may be installed in these zones must meet certain conditions which must also be proven by the respective manufacturer.

Tertiary explosion protection:

If there really is no other way: allowing explosions to occur in a controlled way by limiting their consequences through the use of rupture discs, flame arrestors and/or explosion hatches

ATEX Directive in general:

In order to achieve European harmonization, the European community has decided that

products suitable for explosive environments may only be placed on the market if they are

market if they are designed in accordance with the ATEX (Atmosphere EXplosives) directive.

designed. The European Commission, through standardization institutions such as CENELEC, among others, has had new European Standards (EN) issued,

new European Norms (EN) have been drawn up. These cover all devices and

protection systems for places where dust or gas explosion hazards may exist. With

July 1, 2003, the ATEX 94/9/EC directive (designation: ATEX 95, formerly ATEX

100a) comes into force. In this directive, equipment is divided into groups depending on the scope and level of protection provided, equipment is divided into groups and categories, indicated by means of a new marking. At the same time as ATEX 95, Directive 1999/92/EC (designation: ATEX 137, formerly ATEX 118a) is also in force. This directive concerns the minimum requirements for health protection and safety of workers who may be at risk from explosive atmospheres. For the Netherlands these directives are anchored in the ARBO laws and regulations. The Dutch installation standard NEN 3410 will be replaced by the European harmonized standard EN 60079-14.

ATEX 95:

The ATEX directive covers:

- All equipment (electrical and non-electrical) and protective systems intended for use in hazardous areas.
- safety, monitoring and control devices intended for use outside potentially explosive atmospheres, but which are necessary for or contribute to the safe operation of equipment and protective systems with respect to explosion hazards.

The scope covers places where, as a result of local and operating conditions, an explosive atmosphere may be created by mixtures of oxygen and flammable substances in the form of gases, vapors, mists and dusts under atmospheric conditions, in which combustion spreads to the entire unburned mixture after ignition.

The ATEX directive does not apply to seagoing ships and mobile offshore installations, as well as the equipment on board these ships or installations because they are already covered by the IMO convention (IMO = International Maritime Organization).

According to ATEX, the marking of explosion-proof electrical products is extensive.

At a minimum, the marking for electrical equipment must show:

- name and address of the manufacturer
- CE marking followed by the identification number of the NoBo auditing the production site (only for Category 1 and 2)
- type number of the product
- the Community mark 'Epsilon x in hexagon
- the equipment group
- the applicable category for which the equipment can be used
- EC type certificate number, recognizable by the word ATEX

- manufacturing or serial number (tracking & traceability)
- manufacturing year

ATEX 137:

Directly resulting from this ATEX standard is the obligation to draw up an explosion protection document, consisting of, among other things:

- Identification and assessment of explosion risks.
- Classification of the hazardous area based on frequency and duration of occurrence of a hazardous atmosphere.
- Indication of necessary measures to achieve a safe working environment.

achieve.

Roadmap for the explosion safety document.

The following steps can be taken in an investigation:

1 Determine whether a hazardous area classification is necessary based on things such as:

- The presence of explosive/flammable products
- The quantity of these products
- The duration of the presence of the explosive / flammable products

2 Identification of all hazard sources.

3 Determination of the ventilation conditions at the hazard sources.

4 Determination of emissions from the hazard sources.

5 Determination of the zone class.

6 Determining the dimensions of the hazard zone.

7 Identification of potential ignition sources.

Ultimately, these actions should lead to a report in which all hazard zones, their classification, dimensions and the like thereof are visible. In accordance with the obligations from ATEX 137, this report will have to make recommendations to make the work environment safer. Based on this report, if necessary, measures can be taken to achieve a more optimally safe working environment.

Zone classification:

Explosion hazard area can be classified into the following hazard zones:

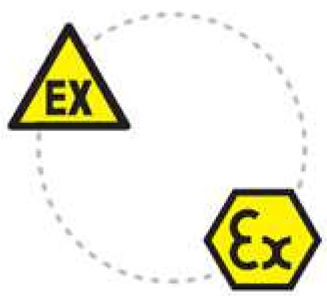
Zone	Description.
0	an explosive gas mixture is present continuously or for long periods of time
1	probability of presence of an explosive gas mixture under normal operation is high
2	probability of presence of an explosive gas mixture is low and only for short periods of time
20	chance of the presence of an explosive dust cloud is continuous or for long periods of time
21	probability of presence of an explosive dust cloud under normal operation is high
22	probability of presence of an explosive dust cloud is low and only for short periods of time

<u>Notes</u>

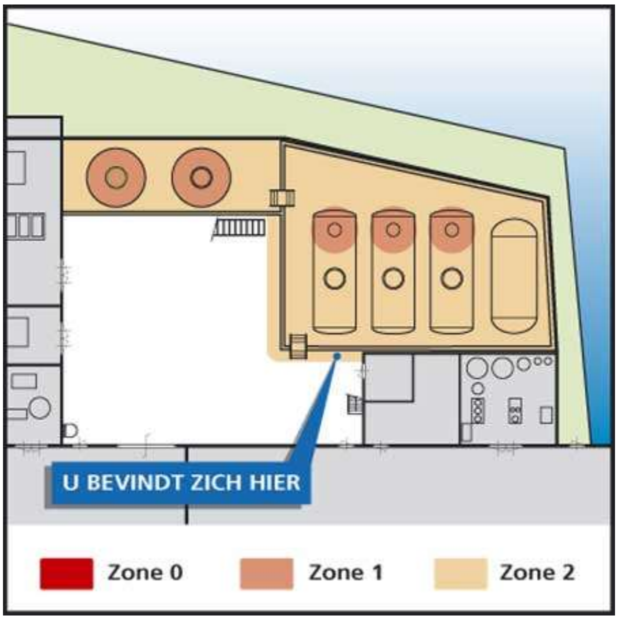
Normal operation means the usual operating situation in which the plant is laid out. Dust layers and dust accumulations that can lead to an explosion hazard must also be observed.

The hazardous area classification for gas explosion hazard is standardized in EN-IEC 60079-10. The danger zone classification for dust explosion hazard is European standardized in EN 50281-3 and international standardized in IEC 61241-10. A Dutch Practical Guideline is additionally available for the Netherlands, as an aid in performing the risk analysis: NPR 7910 parts 1 and 2. Part 1 covers gas explosion hazard, part 2 dust explosion hazard.

Explosion hazard areas should be clearly marked for workers with a warning triangle containing the text “EX” in black on a yellow background. Explosion-proof equipment which has been made suitable for use in hazardous areas by manufacturers in accordance with ATEX Directive 94/9/EC (ATEX 95) is marked with the Community 'Epsilon x' logo in a hexagon. No yellow background requirement applies here.



- Figure 2 Explosive area signage and material equipment designation.



- Figure 3 Zone layout of a factory site.

Equipment and gas groups:

There are currently 2 equipment groups, namely: equipment group I and II

- Equipment group I concerns all underground (mining) installations (methane)

- Equipment group II concerns all other aboveground installations.

Equipment group II is divided into 3 gas groups, namely: gas group IIA, IIB and IIC. Distinctions lie mainly in the MESG (Maximum Experimental Safety Gap) in terms of pressure-resistant encapsulation and the MIE (Minimum Ignition Energy) in terms of intrinsically safe circuits.

Representative gases or vapors of liquids are:

IIA a.o. propane, butane, kerosene

IIB a.o. ethylene, hydrogen sulfide, ethyl ether

IIC a.o. hydrogen, acetylene, sulfur carbon.

There is no subdivision for dust in the current standards harmonized under ATEX Directive 94/9/EC. Due to internationalization of the European standards (there is a shift from EN (European Standards) to IEC (International Standards) we will have to deal with a new equipment group in the future, namely equipment group III. This will be subdivided into IIIA, IIIB and IIIC.

The subdivision will then be characterized as follows:

IIIA combustible flyers (dust particles with a diameter larger than 0.5 mm)

IIIB dusts (dust particles with diameter smaller than 0.5 mm)

IIIC conductive dusts (electrically conductive substances).

In America this has existed for some time, albeit in a different subdivision. Here we know Class I, II & III.

<u>Class I concerns gas explosion hazard (gases and vapors) with subdivision:</u>

Group A e.g. sulphur carbon, acetylene

Group B e.g. hydrogen, ethylene oxide, propylene oxide

Group C e.g. ethylene, hydrogen sulfide, ethyl ether

Group D e.g. methane, propane, butane, kerosene

<u>Class II refers to dust explosion hazard (combustible dusts) with subdivision:</u>

Group E metallic dusts, regardless of electrical conductivity or

other particulates with electrical conductivity less than 10^5 ohm-cm

Group F carbonaceous substances with electrical conductivity between 10^2 and 10^8 ohm-cm

substances with electrical conductivity greater than 10^5 ohm-cm (non-conductive substances)

Class III refers to "easily ignitable fibers and flyings" without further subdivision.

Temperature classes:

When an ignitable cloud of gas or dust comes into contact with an object with a temperature, which is equal or higher than the ignition temperature of this combustible gas or dust, ignition may occur (e.g. heating elements, mechanical drives, electric motors and light bulbs).

In the case of mixtures of different gases or substances, the gas or substance with the lowest ignition temperature is always decisive unless further details are known.

The highest surface temperature, to prevent ignition, must be lower than the ignition temperature of the gas, vapor, mist or dust mixture.

Gas explosion-proof equipment is divided into temperature groups (-classes) or "T-classes". Equipment, which is classified in a certain temperature class, may therefore be used for gases with an ignition temperature, which is higher than the temperature corresponding to that group.

Temperature class	Maximum permissible surface temperature of the material
T1	450 °C
T2	300 °C
T3	200 °C
T4	135 °C
T5	100 °C
T6	85 °C

For dust explosion proof equipment, the classification is not in temperature classes, but regulated by a maximum surface temperature as an absolute value mandatory marked on the equipment.

Also, with dust explosion protection, not only the ignition temperature but also the smoldering temperature (glow temperature) applies as a selection criterion. The ignition temperature is the temperature at which an agitated dust cloud ignites, the smoldering temperature is the temperature at which a 5 mm thick layer of dust on a hot surface begins to smolder. To determine the maximum allowable surface temperature for dust explosion-proof equipment, Tmax must not exceed:Tmax = smoldering temperature - 75K AND Tmax = 2/3 x ignition temperature

Example: lignite

Tmax = smoulder temperature - 75 K -> e.g. lignite 225 ºC - 75 ºC = 150 ºC

Tmax = 2/3 of ignition temperature -> e.g lignite 2/3 * 380 ºC = 254 ºC

The lowest value is decisive. So maximum permissible surface temperature for lignite is 150 °C.

Methods of explosion protection:

Many methods of protection against ignition are possible. The most commonly used methods of protection for gas explosion protection are detailed here. The manufacturer of the equipment decides by which protection method the desired safety category can be achieved. The user bases the choice of equipment on the category classification of the equipment in relation to the zone in which the equipment is used. This relationship is indicated below.

Regarding the relation between which protection method is applicable in which zone, there is an overview in installation standard EN-IEC 60079-14 paragraph 5, but of course in Europe the ATEX directive 94/9/EC is decisive. The equipment must therefore be correctly marked according to the relationship between category (ATEX 95) and zone (ATEX 137).

Zone 0: category 1G

Zone 1: category 2G or 1G

Zone 2: category 3G, 2G or 1G

Zone 20: category 1D

Zone 21: category 2D or 1D

Zone 22: category 3D, 2D or 1D

Protection type Ex d - flameproof enclosure (according to EN-IEC 60079-1 a.k.a. EN 50018)

A flameproof enclosure may contain components, which under normal use may cause sparks, arcs or high temperatures, which in turn could initiate an explosion.

The explosive gas mixture is considered to be capable of being present also inside the flameproof enclosure, but any explosion within the enclosure cannot propagate to the outside atmosphere. Thus, a pressure-tight enclosure is not pressure-tight. The flameproof structure is sufficiently strong to absorb the dynamic (momentary) explosion pressure. The built-up explosion pressure is dissipated through tolerance fitting surfaces (flame quench paths). The flame cools to below the ignition temperature of the surrounding gas.

Ex d material must be marked for gas groups IIA, IIB or IIC. These different gas groups place different requirements on the construction (read: flame quench path) of the casing. Gas group IIC has the most stringent requirements. Furthermore, Ex d material must be marked with one of the temperature classes T1 through T6 or the highest surface temperature. The temperature class or highest surface temperature is determined by the temperature that can occur on the outside of the enclosure under normal use.

Examples of Ex d products are switch boxes, electric motors, socket outlets, etc.

Protection type Ex p - pressurization - internal overpressure (according to EN-IEC 60079-2 a.k.a. EN 50016)

A pressurized enclosure may contain components which, in normal use, may cause sparks, arcs or high temperatures which in turn may cause an explosion.

However, the explosive gas mixture cannot enter the enclosure because it is under overpressure relative to the surrounding atmosphere, with or without continuous flow of protective gas. This may be an inert gas or air.

Ex p products must be marked for equipment group II; no further subdivision into IIA, IIB or IIC is made. The protection mode is not gas group dependent. Furthermore, they must be marked with the temperature class T1 to T6 or highest surface temperature. This temperature class or highest surface temperature is determined by the highest temperature that the outside of the enclosure can assume under normal conditions or by the highest temperature of the electrical material inside the enclosure that is intended to remain in use even if the overpressure is removed.

Examples of Ex p products are control panels, monitors, instrument enclosures, etc.

Protection mode Ex e - erhöhte - increased safety (according to EN-IEC 60079-7 vh EN 50019)

Electrical equipment constructed in accordance with protection type Ex e must not contain any parts which, in normal operation, may cause sparks or arcs which could lead to the ignition of an explosive gas mixture contained in or near the equipment.

The explosive gas mixture is thus considered capable of entering the electrical material. Ex e is thus a mode of protection that is only possible with normal non-sparking equipment.

Ex e material must be marked for equipment group II. Again, a further subdivision into gas group IIA, IIB, IIC is not made. Furthermore, Ex e material must be marked with one of the temperature classes T1 to T6 or with the highest surface temperature. This temperature classification is determined by the highest temperature reached on the outside of the material under normal use.

Examples of Ex e products are terminal boxes, carbon brushless cage anchor motors, etc.

Protection type Ex i - intrinsic safety (according to EN-IEC 60079-11 a.k.a. EN 50020)

For a circuit to be called intrinsically safe, the energy content of the circuit must be limited such that sparks or any other thermal effect cannot lead to ignition of an explosive gas mixture. The energy limitation of intrinsically safe circuits is achieved by limiting both voltage and current. The energy limitation then works quadratically because W = ½LI2 = ½CU2 [J].

The construction requirements for energy limitation apply both to the intrinsically safe circuit itself and to the cables and associated components placed outside the hazardous area because here parasitic capacitances (C) and self-inductances (L) of, for example, long lines may come into play.

Energy limitation also depends heavily on the installation of the intrinsically safe circuit relative to other electrical equipment and on the subsequent installation of other electrical equipment. Here it must be avoided that an intrinsically safe circuit is exposed to disturbances that can nullify the intrinsic safety.

Ex i material must be marked for gas group IIA, IIB or IIC due to gas group dependent minimum ignition energy curves. Ex i material placed in the hazardous area must further be marked for one of the temperature classes T1 through T6. Intrinsically safe material is divided into 2 levels, i.e. Ex ia or Ex ib.

Ex ia material shall not ignite under normal use, at the occurrence of one fault, or at a combination of any two faults.

Ex ib material shall not give ignition under normal use at the occurrence of one fault.

Ex ia material may be suitable for the heaviest category 1G (in that it is still safe at 2 faults) but be aware that this is not necessarily the case. For category 1, additional provisions apply which are laid down in EN 50284 (or EN 60079-26).

Please also note that an intrinsically safe circuit certified for category 1G must comply with Ex ia in its entirety, including those parts located in zone 1 and zone 2 or in the safe area (the so-called 'associated apparatus').

Ex ib material is only suitable for category 2G or 3G.

Examples of Ex i products are transmitters, keyboards (Ex PCs), proximity switches, etc.

Examples of associated apparatus are transmitter barriers, transmitter power supplies, etc.

Protection type Ex o - oil filling (according to EN-IEC 60079-6 vh EN 50015)

Electrical components which may be a source of ignition in contact with explosive atmospheres are so far immersed in oil or another non-flammable insulating liquid that arcing sparks, hot residual gases from high-voltage switching operations or hot components such as starting resistors cannot ignite the gases or vapors above the liquid level and outside the housing.

Important parameters in this construction are:

- captured, insulating liquids, e.g. oil

- monitoring of fluid condition, such as contamination and (condensation) moisture

- ensuring the correct fluid level as occurs with heating and cooling or leakage

- limitation in application for fixed installation only

Scope: large transformers, high voltage switchgear and starting resistors.

Protection mode Ex q - quartz sand filling (according to EN-IEC 60079-5 vh EN 50017)

By filling an enclosure with a fine-grained filler, it is ensured that sparks or arcs of light which may occur in the enclosure cannot ignite the surrounding explosive atmosphere. Of course, limits also apply here to the maximum permissible surface temperature.

Both the filler, such as sand, glass beads, etc., and the construction of the enclosure must meet the requirements laid down in the standard. Under no circumstances, i.e. both under normal operation and after an occurrence of a spark or arc within the sand encapsulation, may the filler leaks out of the enclosure.

Examples of sand encapsulated products are capacitors and electronics that may contain sparks or hot parts, but where the function is not affected by the fine-grained filler.

Protection type Ex m - moulded - encapsulated with moulding compound (in accordance with EN-IEC 60079-18 vh EN 50028)

Electrical parts which could ignite a surrounding atmosphere by sparks or heating can be made explosion proof by completely embedding them in a casting compound. The casting compound must be electrically, thermally, mechanically and chemically resistant.

Important aspects of this method include

- flame deflection resistance

- hygroscopic effects

- the shell must have the minimum (standardized) wall thickness on all sides

- hollow spaces are only permissible to a limited extent

- In general, only electrical connections come out through the casting compound.

Examples of cast-in material are chokes of ballasts, solenoid valves or complete electronic circuits on PCB.

Protection type Ex n - non-ignition (according to EN-IEC 60079-15 a.k.a. EN 50021)

This type of protection is a collection of types of protection which, in a simplified form derived from the already mentioned types of protection, only apply to category 3.

The set of protection methods can be characterized as follows:

Ex nA:

non arcing, non-sparking: only suitable for normal non-sparking equipment.

Ex nC:

closed construction: constructive prevention of a contact in a live circuit being a potential ignition source. Also includes simplified flameproof encapsulation or encapsulation with casting compound.

Ex nR:

Restrictive breathing, restricted breathing enclosure preventing hazardous atmosphere from entering.

Ex nL:

limited energy: a simplified form of intrinsic safety as with Ex ia and Ex ib under EN-IEC 60079-11 vh EN 50020. Analogous to these already known Ex ia and Ex ib variants, it looks like Ex nL will be called Ex ic in the future.

EEx nP:

pressurization, internal overpressure (only in EN 50021). Note: double 'E' This means according to Euro standard. But, because EN 50021 has already been replaced by the international variant EN-IEC 60079-15, this protection mode continues to exist as Ex pz.

Ex pz:

pressurazation, internal overpressure (only in EN-IEC 60079-15). Analogous to the Z-purge methodology for Division 2 in America, this variant of internal overpressure is now internationally accepted and even already harmonized under ATEX (see further section on ATEX Directives).

Both Ex nC and Ex nL are gas group-dependent protection modes so that there will always be a gas group IIA, IIB or IIC listed. Naturally, all variants also include a temperature class. P

ATEX-marking will look like this: