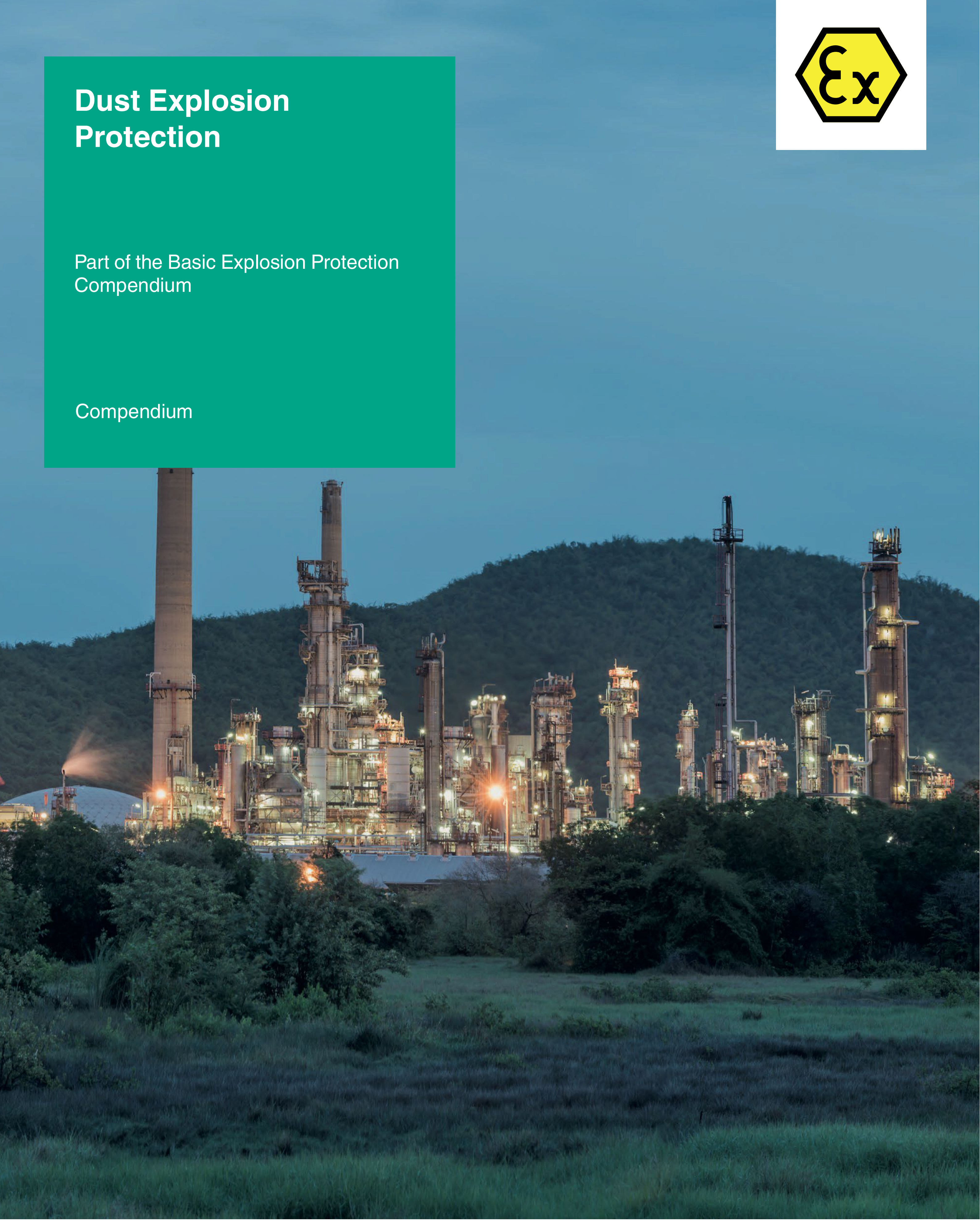
Dust Explosion Protection

Part of the Basic Explosion Protection Compendium

Compendium



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The content of this publication has been compiled by the editor with due and thorough regard of the legal regulations valid at the date of publication and of established technical measures. Nevertheless, incomplete, inaccurate or ambiguous assertions cannot be excluded in the publication. The publication consists of several individual brochures containing general fundamental information on explosion protection. The content of the publication is not intended for and is not suitable for assessing the potential danger of a specific plant.

All regulations on explosion protection are established by German law, including the German Protection at Work Act, and national and international standards. Adherence to these regulations and the German Protection at Work Act are fundamental obligations of the plant designer, plant operator, and employer.

The regulations on explosion protection are subject to legal guidelines and can vary by country.

Furthermore, industrial plants can differ greatly from one another in their design, materials used, and methods of operation. The individual brochures of this compendium provide an overview of topics relating to explosion protection. With this in mind, the technical and organizational measures for explosion protection can only be detailed generally and thus incompletely. In a given specific case, each plant operator must determine his requirements and approach on the basis of an individual hazard assessment, and implement and document these in a fashion verifiable in accordance with the national regulations.

Where necessary, we refer to the relevant IEC/EN standards. Many other countries have comparable national standards. References to national standards are given where required for purposes of clarity and accuracy.

Ask us if you have any questions—we will be happy to help!

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Introduction

Operations and companies handling combustible materials are at risk of explosions. In the event of an explosion, lives, occupational safety, hygiene, and health are always at risk. Individual and hazard-based explosion protection measures ensure the safety and health of people as well as the safety of plant and goods.

There is an immediate hazard to people due to flame and pressure effects that can result from an explosion pressure of up to 10 bar when flammable gases or liquid vapors are ignited.

A pressure surge of 10 bar with a force of 100 t/m^2 would not only destroy masonry, but kill every person in the vicinity. The pressure flow for combustible dusts is even more extreme. Here the explosion pressure can reach up to 14 bar **and** can trigger subsequent explosions by further stirring up the deposited dust.

Even if employees are adequately protected from the direct pressure effects, the sudden removal from the ambient atmosphere of the oxygen required to breathe and the release of harmful reaction products and flue gases can create other serious sources of danger.

Further Information

For further information on the explosion risks and causes, please refer to the following Pepperl+Fuchs brochure:

Pepperl+Fuchs, ed., Physical-technical principles—Terminology definitions, explosions, examples, prerequisites, combustible substances and characteristic values, ignition sources.

Explosion Protection as Occupational Safety and Health

Explosion protection is anchored in occupational safety and health. Compliance with the occupational safety and health laws is in principle an employer obligation; these laws are subject to regulations that differ from country to country. Within the European Union, there are several directives relating to explosion protection:

Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres.

Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work

Directive 1999/92/EC of the European Parliament and Council of December 16, 1999 regarding minimum provisions to improve health protection and safety of employees who may be endangered by potentially explosive atmospheres (Fifteenth Individual Directive for the Purpose of Article 16, Para. 1 of Directive 89/391/EEG)

- ATEX Directive 2014/34/EU is intended to facilitate free trade within the EU and is aimed at manufacturers of devices and protection systems.
- Directive 98/24/EC requires workers to be protected against explosions and their effects.
- Directive 1999/92/EC sets this out in more detail for the protection of workers against explosion hazards connected to potentially explosive atmospheres.

For the individual EU member states, these EU Directives have been implemented in the respective national legal system. For Germany, this comprises the following legislation:

- Hazardous Substances Ordinance
- Ordinance on Industrial Safety and Health

In Germany, these regulations are substantiated, and form the legally sound basis for specific technical and organizational measures, in the form of the German "Technical Rules for Hazardous Substances" (TRGS) and the "Technical Rules for Occupational Safety" (TRBS). These rules define the state of the art, which is regarded as the benchmark in terms of occupational and operational safety. The employer and its officers are therefore strongly advised to comply with these technical rules. The employer can only guarantee the safety and health of employees and the safety of plant and goods by implementing individual hazard-based explosion protection measures. All occupational safety and health measures and therefore all explosion protection measures are based on the results of the hazard assessments.

Carrying Out a Hazard Assessment

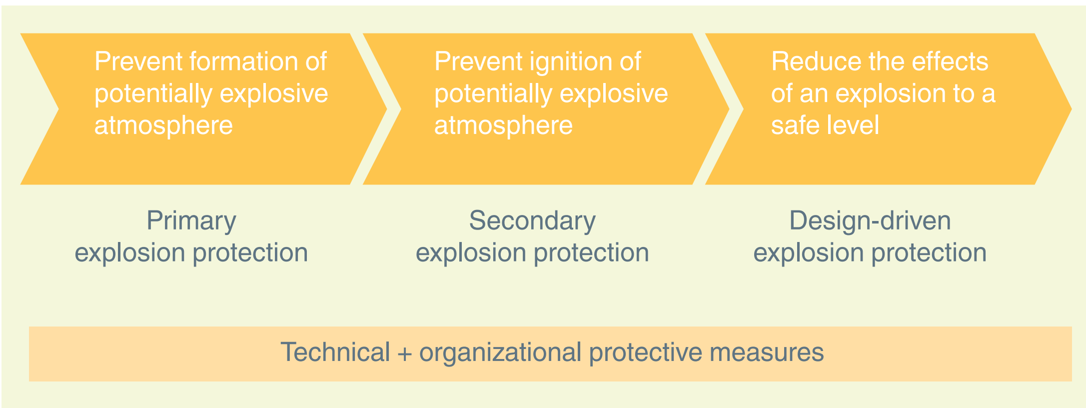
Hazard assessments identify, among other things, the causes of releases of possible ignition sources or interactions between the processed substances. In addition, there are potential hazards that could arise from interactions between work equipment or in combination with the materials processed. Risk assessments must also take into account specific, noncompliant, foreseeable errors. Overall, the following conditions are conceivable:

- Normal "intended" operating conditions, including commissioning, maintenance work, and decommissioning
- Exceptional conditions that may occur in the event of deviations from intended operation, e. g., a power failure
- Foreseeable misuse of the equipment that may create or release a potentially explosive atmosphere, or that may allow potential ignition sources to become active

Integrated Explosion Protection in Germany

When defining protective measures against explosion hazards, the listed order of precedence of integrated explosion protection must be observed:

Integrated Explosion Protection



In Germany, the order of precedence of integrated explosion protection is based on the general principles of occupational safety and health laws:

"Work must be structured such that a hazard to life and health is avoided as far as possible and the residual hazard is minimized … Hazards must be combated at their source."

In addition, there are legal requirements under the Hazardous Substances Ordinance with a general reference to explosion hazards. In accordance with the Hazardous Substances Ordinance, the following sequence must be observed when defining protective measures against explosion hazards:

1. Prevention of the formation of hazardous explosive mixtures
   (primary explosion protection)
2. Prevention of the ignition of hazardous explosive mixtures
   (secondary explosion protection)
3. Mitigating the harmful effects of an explosion to a safe level
   (design-driven explosion protection)

The Hazardous Substances Ordinance specifies further requirements with regard to potentially explosive atmospheres:

"The employer must determine whether the substances, mixtures, and products used […] may cause fire or explosion hazards. In doing so, the employer must assess

1. whether hazardous quantities or concentrations of hazardous substances that could cause fire and explosion hazards are present; […]
2. whether ignition sources or conditions that may trigger fires or explosions are present, and
3. whether harmful effects of fires or explosions on the health and safety of workers are possible."

Typical measures for observing primary explosion protection are using noncombustible substances, preventing releases, and displacing the atmospheric oxygen (inertization of the plant interiors). Further measures include extracting emissions and diluting an existing gas concentration using mechanical or natural ventilation measures. The latter measures are often combined with monitoring the fuel concentration in operational areas.

The Specifics of Handling Dusts

The overriding aim of primary explosion protection is to prevent a potentially explosive atmosphere from arising. If the prevention of the potentially explosive atmosphere cannot be completely guaranteed, measures must be taken to limit the potentially explosive atmosphere, both in terms of time and space. Although only the dispersed dust cloud can explode, the deposited dust also poses a particular risk. There are several reasons for this:

- Deposited dust has a smolder temperature
- Deposited dust can be dispersed at any time
- The amount of deposited dust can accumulate
- The smolder temperature of the dust reduces when the layer thickness increases
- Equipment emits fewer thermal losses when the layer thickness is increased and becomes hotter

Removing deposited dusts is therefore an important measure for primary explosion protection.

What are Dusts?

Dust is understood to mean small solid particles with a nominal size of 0.5 mm or less that can be suspended in the atmosphere or can be deposited on surfaces under their own weight. Specifically produced materials of this type include powders and flours. Dust can also occur as a result of abrasion during the transportation of coarse-grained material (e. g., grain) or when processing and machining solids (e. g., as sawdust or grinding dust).

What are Combustible Dusts?

Combustible dusts are materials that can smolder or burn as heat builds up in the presence of oxygen (e. g., air). These include wood, coal, grain, plastic materials, and many metals, where present in a fine form. If a dust layer is ignited, a combustion will occur. A dust combustion can develop into a dust explosion.

Dust Explosion

The production, processing, transportation, storage, or packaging of combustible dusts, fibers, and flyings pose a risk of release. Dust layers can form as a result. If these layers are dispersed into a dust cloud with a sufficiently high concentration, they can lead to hazardous explosions.

As soon as a primary explosion has been triggered, further deposited dust can be dispersed, and several subsequent explosions can occur in a chain reaction. This state of affairs features prominently in the risk assessment, as in this case explosive dust/air mixtures, and active ignition sources are no longer independent of each other in terms of their probability of occurrence.

Dust explosions are a frequently underestimated hazard: **A dust explosion occurs every day in Germany.**

Processing industries for wood, plastic material, and metal, as well as industrial production sites in the agriculture, chemicals, animal feed, food, and paper sectors are at a particular risk of dust explosions. Explosions often occur in bunkers, separators, and silos.

Note

Physicochemical Process

Dust explosions are quick exothermic oxidation reactions. The prerequisite is that combustible, dispersed, and sufficiently fine dust is present, in the relevant concentration, and mixed with a gaseous oxidizing agent, e. g., atmospheric oxygen. If this mixture comes into contact with an ignition source with sufficient energy, a dust explosion will be triggered.

For an explosive reaction of this type, the fuel and oxidizing agent must have been thoroughly mixed immediately prior to ignition. The reaction then propagates rapidly without any further external energy input, inflames the mixture, and heats up the atmosphere very quickly.

This results in significant pressure increases, especially in closed containers or rooms. Possible consequences include mechanical destruction and substance releases.

Which Processes Generate Dusts?

The following tasks, among others, pose a risk of dust explosions:

- Grinding/drying coal
- Filling coal dust silos
- Coal dust suction
- Suction and conveying of wood dust in filters and separation plant
- Turning and ensilaging grain
- Grinding, mixing, and mechanical conveying of organic products. These include grain, animal feed, sugar, plastic materials, colorants, and pharmaceuticals
- Spray drying of organic products, e. g., milk
- Drying, granulating, coating in fluidized-bed apparatus, e. g., processing sewage sludge
- Grinding light metals and their alloys
- Manufacturing and processing metal powders
- Emptying bulk containers, e. g., flexible intermediate bulk containers (FIBC)

Classification of Equipment

In the European Union, explosion hazards in (underground) mining and explosion hazards outside mining are considered separately, as can be seen in the ATEX Directive 2014/34/EU.

To differentiate, the European Directive uses Group classifications "I" (mining) and "II" (other areas outside mining).

Directive 2014/34/EU subdivides Group II further into Group IIG (gases) and Group IID (dusts). The scope of the Directive determines "atmospheric conditions." This relates to situation in which combustible substances are released into breathing air, thereby endangering employees.

As international device standardization is now technically implemented by the International Electrotechnical Commission (IEC), there are discrepancies within dust markings. The reason for this is that the IEC has further segmented the marking system for electrical apparatus for explosive atmospheres. Now the technical marking for Group II is used only for devices that are used with gases.

With the introduction of Group III, devices that are intended for use together with dusts are marked. This segment allows for a further subdivision of Group III into IIIA ... IIIC by dust type.

Group IIIA: Combustible Flyings

Combustible flyings are small solid particles, including fibers with a nominal size greater than 0.5 mm. Such flyings may be suspended in the atmosphere, with the risk of settling under their own weight, burning or glowing in the air, and forming explosive mixtures with the air at atmospheric pressure and normal temperatures.

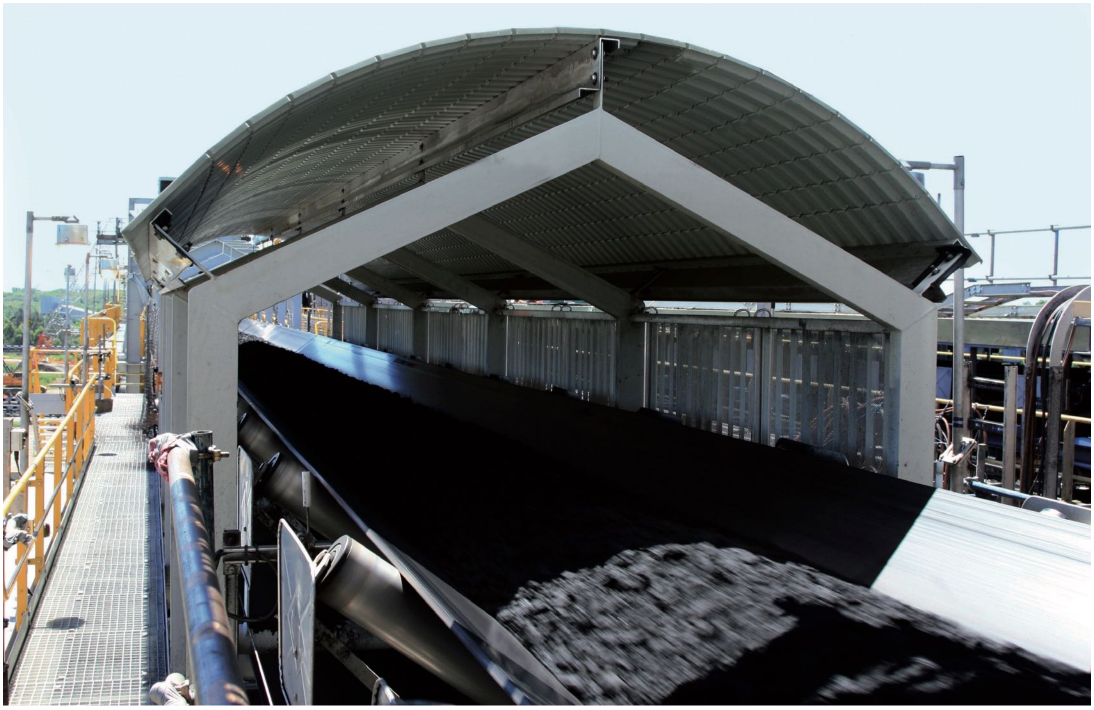
Group IIIB: Nonconductive Dust

Nonconductive dust is combustible dust with a specific electric resistance $> 10^3\ \Omega m$.

Group IIIC: Conductive Dust

Conductive dust is combustible dust with a specific electric resistance $\leq 10^3\ \Omega m$.

Release of Dust Caused by Transportation of Coarse Solids



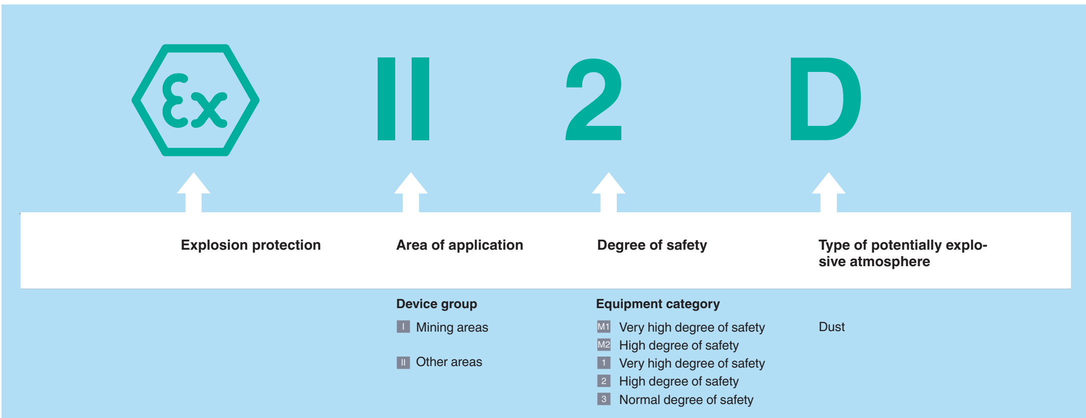
ATEX Marking

With the introduction of ATEX requirements, a new marking program came into force for all products intended for use in the EU. The marking requirements are aimed at uniformity. The CE conformity marking on a product indicates that all relevant directives have been observed and that the product is suitable for use in accordance with the manufacturer's instructions. These directives may include: ATEX Directive 2014/34/EU, the Low Voltage Directive 2014/35/EU, the Electromagnetic Compatibility Directive 2014/30/EU, the Machinery Directive 2006/42/EC, etc.

The following marking information currently applies to products for use in hazardous areas:

Equipment Group	Equipment category	Probability of potentially explosive atmosphere	The degree of safety to be guaranteed	Comparison with the previous Group and zone classification
I (Mine gas, combustible dusts	M1	Present	Very high	Group I
	M2	Can be switched off if atmosphere occurs	High	Group I
II All other areas except I Mixtures of air and gases, vapors, mist, dusts)	1	Present permanently, for prolonged periods, or frequently	Very high	Group II Zone 0 Zone 20
	2	Occasionally present	High	Group I Zone 1 Zone 21
	3	Not present, or rarely present, and then only briefly	Normal	Group I Zone 2 Zone 22

Legal Marking according to ATEX



Basis for equipment selection: zone classification (user's responsibility)
Application in dust hazardous area

Zone	Area in which a dangerous potentially explosive atmosphere in the form of combustible dust contained in the air ...
20	... is constantly, persistently, or frequently present.
21	... can occasionally form during normal operation.
22	... does not usually arise during normal operation and, if so, only rarely and for a short period of time.

Equipment categories for dust hazardous areas (ATEX)

Zone	Group	Category	Additional
20	II	1	D
21	II	2	D
22	II	3	D

Typical EPL (IEC or EN 600079-...)

Zone	EPL
20	Da
21	Db
22	Dc

Safety Parameters

The safety parameters are quantitative statements about substance characteristic that are decisive in assessing explosion hazards. Apart from a few exceptions, these characteristics are not physical constants, but depend on the determination method and usually only apply to atmospheric conditions. Some of the characteristics are required to select the equipment for use in dust hazardous areas. Others are basic parameters for design-driven explosion protection. In the case of design-driven explosion protection, the explosion effects are confined to within a reasonable scope. Suitable design measures include the following:

- Explosion-proof design
- Explosion pressure relief
- Explosion suppression

The explosion characteristics are primarily dependent on the composition of the dust. The dust sample must be examined to determine the characteristics. The grain size, purity, and humidity play an important role in determining the combustibility and explosion behavior.

As the water content increases, the ignition sensitivity of combustible dusts decreases. Above a water content of 20 percent by weight … 30 percent by weight, the maximum explosion pressure rise and dust explosion classes are reduced.

When considering the safety parameters, a distinction is made between deposited dust and dispersed dust.

Deposited combustible dust can result in hazardous potentially explosive dust/air mixtures through being dispersed, which can lead to an explosion if an ignition source is present.

Deposited Dust: Safety Parameters

Important safety parameters for deposited dust are:

- Combustion behavior
- Minimum ignition temperature, i.e., smolder temperature of the dust layer
- Self-ignition behavior
- Impact sensitivity
- Decomposition

Dispersed Dust: Safety Parameters

Important safety parameters for dispersed dust are:

- Explosion pressure
- Explosion limits
- Minimum ignition temperature for dust cloud
- Median value
- Minimum ignition energy
- Self-ignition temperature
- Dust explosiveness
- Dust explosion classes

Reference Works on Safety Parameters

Comprehensive reference works are available for the safety parameters. The following are examples of important publications:

VDI Directive 2263 Dust fires and dust explosions - Hazards - assessment - protective measures

This Directive deals with equipment and plant that exhibit special features in process engineering that lead to special protective systems for both fire and explosion protection.

Sheet 1: Test methods for the determination of the safety characteristic of dusts

Sheet 2: Inerting

Sheet 3: Pressure-shock-resistant vessels and apparatus; calculation, construction and tests

Sheet 4: Suppression of dust explosions

Sheet 5: Explosion protection in fluidized bed dryers

Sheet 6: Dust fires and explosion protection in dust extracting installations
Sheet 6.1: Examples

Sheet 7: Dust fires and explosion protection in spraying and drying integrated equipment
Sheet 7.1: Examples

Sheet 8: Fire and explosion protection on elevators
Sheet 8.1: Examples

Sheet 9: Determination of dustiness of bulk materials

VDI Directive 3673 Pressure venting of dust explosions

The Directive describes one of the possible measures to reduce the impacts of dust explosions and provides guidance on the selection and dimensions of pressure relief systems.

- TRD 413—Coal dust firing systems on vapor boilers (Kohlenstaubfeuerungen an Dampfkesseln)
- TRD 415—Fluidized-bed combustion systems on vapor boilers (Wirbelschichtfeuerungen an Dampfkesseln)
- Guidelines of the Technical Committee for Plant Safety (TAA)
- TAA-GS 33 Potentially explosive dust/air mixtures and the Major Accidents Ordinance (Explosionsfähige Staub-Luft-Gemische und Störfallverordnung)
- GESTIS-Dust-EX database of combustion and explosion characteristics of dusts of the Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA, formerly the BGIA)
- BIA Report 12/97 Combustion and explosion characteristics of dusts
- BGI 747 Information sheet R003 (plant safety) Safety parameters—Determining and evaluating
- DGUV rule 113-001, explosion protection rules (Ex-RL)

Atmospheric Conditions

Atmospheric conditions are defined as follows:

- Temperature range of -20 °C … +60 °C
- Pressure range of 800 hPa ... 1100 hPa (0.8 bar … 1.1 bar)
- Oxidizing agent: air (oxygen concentration 21 vol.%)

Combustion Behavior

The combustion behavior describes how strongly and how quickly an ignited dust layer is burned off. To this end, a dust jetty with a width of 2 cm and length of 4 cm is attached to a ceramic plate. Then an attempt is made to ignite the dust with a gas flame or a red-hot platinum wire.

The combustion behavior of the dust sample is evaluated and the dust is classified with a flammability class (BZ).

BZ 1 means "no combustion," BZ 6 means "explosive burning or rapid flameless decomposition."

The flammability class can also change as the ambient temperature increases. For example, potato starch is noncombustible at normal ambient temperatures, but highly combustible at higher temperatures.

Combustion behavior		Flammability class (BZ)	Example
No fire propagation	No ignition	1	Table salt
	Short ignition and rapid extinction	2	Tartaric acid
	Localized burning and smoldering with limited propagation at most	3	Lactose
Fire propagation	Aglow without sparking (smoldering fire) or slow, flameless decomposition	4	Tobacco
	Propagation of an open fire or burning off with spraying sparks	5	Sulfur
	Explosive burning or rapid, flameless decomposition	6	Black gunpowder

Explosion Pressure

The maximum explosion (over)pressure p_{max} is the maximum pressure determined under prescribed test conditions that occurs in a closed container in the event of an explosion of a dust in a mixture with air.

Explosion Limits

As in a gas hazardous area, there are concentration limits in a dust hazardous area within which the dust/air mixture is explosive.

There is insufficient combustible dust present below the lower explosive limit (LEL). The mixture is too lean. There is insufficient oxygen present above the upper explosive limit (UEL). The mixture is too rich. A mixture is explosive between the LEL and the UEL, and there is therefore an explosion hazard. The explosion limits are material-based values and are specified in g/m^3.

The LEL for dust is determined through experimentation in a closed, roughly spherical pressure container with an associated control unit. Since the UEL of dust has little significance for safety concepts, it is only determined in exceptional cases.

Explosion Limits of Frequently Used Substances

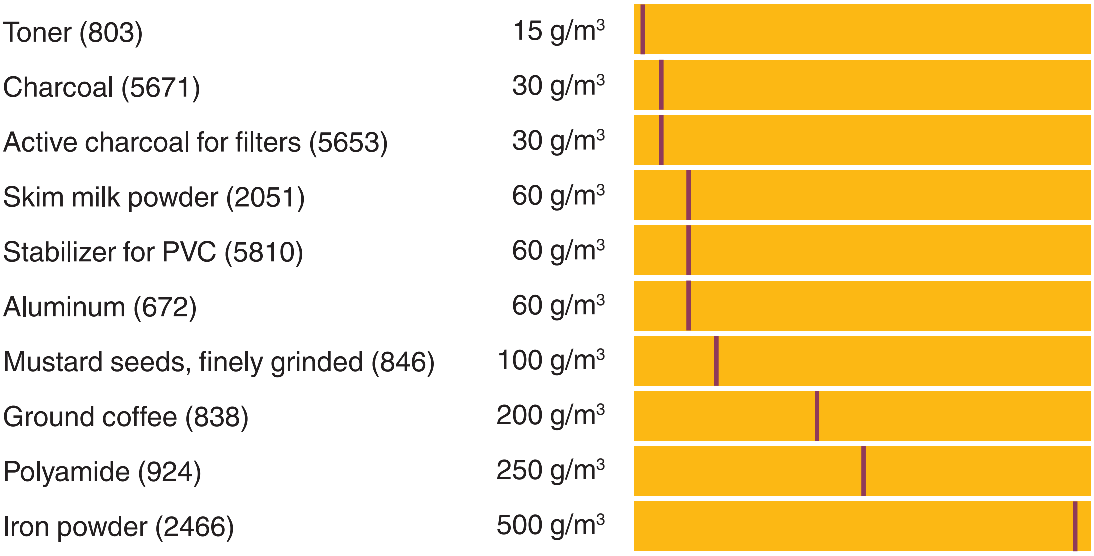


Figure 3.1 Source: Gestis database of hazardous substances (GESTIS substance IDs in brackets)

20 I Apparatus for Determining the Pressure Increase Over Time (Kühne AG)

Median Value

The median value is the average grain size value. This means that 50 percent by weight of the dust is coarser than the given median value, and 50 percent by weight is finer.

The median value is usually determined through a sieve analysis.

Note

Procedure for Determining the Grain Size Distribution

The grain size distribution of bulk materials can be performed using the sieve analysis. The procedure is described in German standard DIN 66165.

The method most commonly used for the sieve analysis is dry sieving with a sieve tower attached to a sieve machine. During sieving with a sieve tower, several test sieves are arranged one above the other and clamped onto a sieve machine. The mesh sizes of the individual test sieves are arranged in descending order from top to bottom. For the sieve analysis, the sample to be analyzed is placed in the coarsest test sieve and subjected to a defined movement for a specified period of time. The grain size distribution of the sample is determined by weighing the residues on each test sieve.

Minimum Ignition Energy

The minimum ignition energy is defined as the lowest energy stored in a capacitor that, when discharged, is sufficient to ignite the ignition of the most ignitable potentially explosive atmosphere under specified test conditions.

The minimum ignition energy (MIE) of combustible dusts is typically much higher than that of gases and vapors. The MIE of dust depends on the grain size, the surface structure, and the material moisture.

Minimum ignition energy	Type of dust	Example
< 1 mJ	Extremely flammable	Aluminum dusts
1 mJ ... 10 mJ	Highly flammable dusts	Wax dusts
> 10 mJ ... 100 mJ	Moderately flammable dusts	Sugar dusts, milk powder dusts
> 100 mJ	Low-flammable dusts	Wheat flour, coal dusts

Minimum Ignition Temperature of a Dust Layer

The minimum ignition temperature of a dust layer or the smolder temperature is the lowest temperature of a hot surface at which the ignition of a dust layer of a specified thickness on this hot surface occurs.

The minimum ignition temperature for a dust layer with a thickness of 5 mm is referred to as the smolder temperature.

When selecting an apparatus, its maximum surface temperature as per the manufacturer's specification or EU type-examination certificate must be at least 75 K below the ignition temperature of a 5 mm dust layer.

The previously valid methods and the method now used are briefly outlined below.

Formerly according to DIN EN 61241-1

DIN EN 61241-1, protection by enclosures "tD," featured two different methods that were used to determine the maximum surface temperature with a dust layer.

- Method A

  The maximum surface temperature is determined without a dust layer, and erection regulations require a difference of 75 K between the surface temperature and the smolder temperature of a particular dust.

- Method B

  The maximum surface temperature is determined with a 12.5 mm thick dust layer, and erection regulations require a difference of 25 K between the surface temperature and the smolder temperature of a particular dust.

The method type influenced the selection of the apparatus, depending on whether the apparatus was marked with Ex tD A or Ex tD B:
When marking according to method A, the surface temperature had to be 75 K lower than the smolder temperature of the dust layer concerned.
When marking according to method B, the surface temperature had to be 25 K lower.

Currently according to IEC/EN 60079-31

DIN EN 61241-1 has been replaced by IEC/EN 60079-31 Equipment dust ignition protection by enclosure "t."

In the new standard, methods A and B have been combined and simplified to create a uniform method.

The marking of the apparatus with Ex ta, Ex tb, or Ex tc no longer distinguishes between methods A and B.

Devices with level of protection "ta" can be used, for example, in a silo, whereby these devices can be operated in dust dumping scenarios.

The manufacturer makes its temperature specification based on a thermal examination of the entire surface of the enclosure with a dust dumping that is at least 200 mm thick.

Ignition Temperature of a Dust Cloud

The ignition temperature of a dust cloud is the lowest temperature of a hot melting-furnace interior wall where the ignition of a dust cloud occurs in the air contained in the furnace.

The maximum surface temperature of an apparatus may not exceed two thirds of the ignition temperature of the dust cloud.

When selecting an apparatus, its surface temperature as per the manufacturer's specification or EU type-examination certificate may not exceed two thirds of the ignition temperature of the dust cloud.

Chemical substance	Median value D_M [μm]	Ignition temperature of cloud T_Z [°C]	Ignition temperature of layer T_G [°C]	Auto-ignition temperature T_{SE} [°C]
Brown coal	51	380	220	100
Medium volatile coal	28	630	250	100
Active charcoal	23	780	> 400	250
Wood waste	45	590	360	190
Sewage sludge	31	450	270	140
Meat-and-bone meal	182	520	> 400	165
Color powder	< 20	> 1000	360	180

Dust Explosiveness

Dust explosiveness is given if a flame that is connected to a temperature and pressure increase in a closed container is propagated in a dust/air mixture after ignition. Based on their K_{st} values, the dusts are divided into classes.

Dust-Specific, Volume-Dependent Characteristic (K_{st})

The K_{st} value is a dust-specific, volume-dependent characteristic that classifies the reaction behavior of a dust. The K_{st} value describes the explosiveness of a dust. The reaction behavior of a dust is described by the maximum explosion pressure and the explosion pressure rise over time.

The K_{st} value is calculated from the cubic law. According to the cubic law for the volume dependency of the maximum rate of explosion pressure rise, the following applies:
$(dp/dt)_{max} V^{1/3} = \text{constant} = K_{st}$.

The K_{st} value is numerically equal to the value of the maximum rate of explosion pressure rise $(dp/dt)_{max}$ measured in a 1 m^3 container under prescribed test conditions.

K_{st} value [bar x ms^{-1}]	Dust explosion class
... < 200	St 1
200 ≤ … ≤ 300	St 2
300 ≤ ...	St 3

Auto-Ignition Temperature

The auto-ignition temperature relates to a deposited dust layer, which ignites itself when subjected to a thermal effect on all sides in the presence of air, without any other ignition sources. Spontaneous ignition is caused if the rate of heat production of the oxidation reaction or decomposition reaction is higher than the thermal loss rate from the dust layer. If a sample exceeds the ambient temperature by more than 60 °C, this is referred to as spontaneous ignition. The resulting heat of reaction can also cause a low-temperature carbonization gas that is able to form an explosive gas/air mixture.

Maximum Permissible Surface Temperature

The maximum permissible surface temperature is the highest temperature that the surface of electrical or nonelectrical equipment may reach during intended operation to avoid ignition.

The maximum permissible surface temperature depends on the following factors:

- Type of dust occurring
- Form of occurrence as cloud or layer
- Amount of dust or layer thickness
- Application of a safety factor

Ignition Sources

When using equipment and operating plant within dust hazardous areas, it must be checked whether ignition hazards will occur. Ignition sources provide unwanted energy input in hazardous areas.

If a potentially explosive dust atmosphere comes into contact with heated surfaces, the atmosphere may be ignited. The energy contained in a spark can also be the cause of the ignition.

To avoid ignition, these potential sources are either generally avoided or, if this is not possible, safety margins on the limit values of the ignition hazards are specified. These limits are based on the characteristics and on how combustible dusts are handled.

One example is intrinsic safety. Here, an energy limitation ensures that the ignition source "electrical current" cannot become effective. This means that a safety margin is maintained between the maximum possible amount of energy of the intrinsically safe circuit and the minimum ignition energy required for the dust/air mixture. To be able to set safety margins, the minimum ignition energy and the minimum ignition temperature of the dust/air mixture must be known.

Potential Ignition Sources and Causes

Ignition source	Cause, examples
Hot surface	Electricity in electrical installations, radiators, machining, friction heat (brakes, lack of bearing lubrication)
Flames and hot gases	From combustion reactions, flying sparks during welding
Mechanically generated sparks	Spark created by ablation processes (grinding), friction, impact effect (especially rust/light metals). Foreign matter in moving parts
Electrical installations	Opening/closing of contacts, loose contact. Safety extra-low protective voltages (U < 50 V) can also generate sufficient energy to ignite a potentially explosive atmosphere.
Electrical equalization currents	Reverse currents of generators, short circuit to frame/ground in the event of faults, induction, cathodic corrosion protection
Discharge spark	Spark by friction of insulating materials, discharge of charged persons, substances, components, etc.
Lightning	Atmospheric weather disturbances
Electric arc	Short circuit, switching operation
High frequency $9 \times 10^3 \ldots 3 \times 10^{11}$ Hz	Radio signals, industrial high-frequency generators for heating, drying
Electromagnetic waves in the range 3×10^{11} Hz to 3×10^{15} Hz	Laser beam for distance measurement, photo flash, laser welding
Ionizing radiation	X-ray device, radioactive materials, energy absorption leads to heating
Ultrasound	Energy absorption in solid/liquid substances leads to heating
Adiabatic compression	Sudden opening of valves, shock waves
Exothermic reaction	Chemical reaction with heat release

Possible Ignition Hazards at the Workplace

Hazardous Areas

Measures against Hazardous Potentially Explosive Atmospheres

A hazardous potentially explosive atmosphere can be prevented or restricted using the following explosion protection measures:

Avoidance or restriction of substances that can form a potentially explosive atmosphere.

It must be checked whether combustible substances can be replaced with substances that cannot form explosive mixtures. For example, can combustible dusty fillers be replaced with noncombustible fillers?

Prevention or restriction of a potentially explosive atmosphere in the interior of plants and plant parts.

If handling substances that may form a potentially explosive atmosphere cannot be avoided, the formation of a potentially explosive atmosphere in hazardous quantities within plants and plant parts can be prevented or restricted by limiting the quantity or concentration or by rendering hazardous components inert. If the concentration quantity of potentially explosive substances is limited, the existing concentration can be kept below the lower or above the upper explosion limit.

In the case of dusts, it is difficult to prevent explosive mixtures by limiting the concentration. In particular, the interaction between dispersed and deposited dust must be observed. Homogeneous dust/air mixtures are extremely rare. It is therefore only rarely possible to consider as the dust concentration the total amount of dust in relation to the entire room or the total volume of a piece of work equipment including plants and plant parts, assuming an even distribution. In the case of inhomogeneous dust distribution, there may be an explosion hazard in plants and plant parts as well as in containers or rooms, even if the amount of dust relative to the total volume is outside the explosion limit.

During inertization, the formation of explosive mixtures can be prevented by adding gaseous inert materials or powdered inert materials. Gaseous inert materials can include nitrogen, carbon dioxide, noble gases, and water vapor.

For inertization to work effectively and reliably, the process must be monitored and safeguarded. This can be done, for example, by monitoring the oxygen concentration, the inert gas concentration, the total pressure, or the flow rates of inert gas and combustible material. An alarm threshold must be set below the maximum permissible oxygen concentration. When the alarm threshold is reached, protective measures must be triggered and implemented manually or automatically, depending on the scenario. The alarm threshold to be defined, the characteristics of the monitoring systems, their required functional safety, and the reaction times of the personnel and the plant must be coordinated. Depending on the reliability of the inertization, a zone reduction is possible for the interior of containers and plant parts. TRBS 2152-2 provides detailed information on the inertization of potentially explosive atmospheres from combustible dusts.

Measures to Counteract Potentially Explosive Atmospheres in the Vicinity of Plants and Plant Parts

In the vicinity of plants and plant parts, the formation of a hazardous potentially explosive atmosphere must be prevented or restricted, as far as this is possible within the scope of the state of the art.

Cleaning

In the case of dusts, it is particularly important to consider that unwanted dust layers can also form at a distance from the exit point, which is particularly true of very fine-grained dust. These can then form potentially explosive atmospheres as a result of dispersion. If deposited dust with a layer thickness of 1 mm is dispersed, this creates a dust cloud that is already capable of being ignited. As a protective measure, frequent and thorough removal of the dust layers without dispersion is necessary.

It is also possible to at least temporarily prevent a dust layer from forming a potentially explosive atmosphere by humidifying the dust layer or by overlaying powdery inert materials.

No dust may be dispersed during cleaning. Common methods are:

- Wet cleaning methods
- Removal using vacuum cleaners

The vacuum cleaners must be explosion-protected to prevent them from acting as an ignition source. Structural and design measures must be taken to make cleaning easier for personnel. Horizontal surfaces on which dust can deposit are to be avoided. For cable trays, chamfered roofings help, which systematically channel the dust onto the floor or into areas that are easily and safely accessible. Walls must be as smooth and jointless as possible. Floor markings in conjunction with cleaning schedules help ensure that hazardous layer thicknesses do not build up unnoticed.

Selection of hazard-reducing materials

Hazards caused by reactions of wall material with combustible materials/mixtures must be excluded. The corrosion behavior must be taken into account when selecting the materials. In case of extensive ablation, an extra amount of material must be taken into account when calculating the wall thickness. Suitable materials must be selected as a basic protective measure against pitting corrosion and appropriate preservation measures must be taken during standstill phases.

Dust-tightness (permanently technically tight design)

No release of dust is anticipated for plant parts that are permanently technically tight. Plant parts are considered to be permanently technically tight if they remain technically tight on the basis of their design or their technical dust-tightness is perpetually guaranteed through maintenance and monitoring.

Plant parts that are permanently technically tight do not create hazardous areas when unopened in their environment due to their design.

Examples of permanently technically tight plant parts and equipment parts that remain technically tight based on their design include:

- Welded plant parts with detachable components, whereby the necessary detachable connections are rarely required to be detached during operation and are designed in the same way as the detachable conduit connections described below (with the exception of metallically sealing connections)
- Detachable connections with rigid conduits, fittings, or blind covers, whereby the necessary detachable connections are rarely required to be detached and are designed in the same way as the detachable rigid conduit connections
- Plant parts that can also contain sealing elements; these include: shaft bushings with monitored sealed air, e.g., in the case of labyrinth seals or stuffing box seals, fittings with standard sealing systems, e.g., disk valves, closed-type sliders, ball taps, magnetically coupled, seal-less drive systems

Due to their design, the following conduit connections remain permanently technically tight:

- Self-adjusting stuffing box packings when checking the right fitting and checking the wear limit
- Single-action sealing systems only for plants
  - Without internal overpressure
  - With low mechanical and thermal stress
  - With low vibration loads, e.g., on screw conveyors, troughed chain conveyors

The scope and frequency of monitoring and maintenance depend on the type of connection and design, mode of operation, stresses, and the condition and characteristics of the materials. These measures are designed to permanently guarantee technical tightness. The scope and frequency of monitoring and maintenance to permanently maintain technical tightness must be specified in the explosion protection document among the documents listed there. Documents of this type include, for example, an associated instruction manual or a maintenance schedule.

On-site inspection of the plant and checking for dust leakage and dust layers is sufficient for monitoring. Appropriate preventive maintenance can reduce the scope and frequency of monitoring for leaks.

The release of dust is rarely anticipated for plant parts that are technically tight. Plant parts are considered to be technically tight if a tightness inspection or tightness monitoring suitable for the application scenario in question in the form of regular checks for dust leakage and dust layers as well as for visible signs of faults or damage reveal no evidence of leaks.

Examples of technically tight plant parts for dusts include:

- Compensators
- Flexible connections
- Stuffing box seals
- Detachable connections that are not, or only rarely, detached
- Manholes and inspection openings that are not, or only rarely, opened

Safeguarding operational exit points

In the case of plant parts that are neither permanently technically tight nor technically tight, the formation of a hazardous potentially explosive atmosphere must be expected due to the operational escape of dusts. An example of operational exit points for dusts are transfer points.

Technical measures can be taken to reduce the quantities of dust escaping, zone expansion, or the likelihood of a potentially explosive atmosphere occurring. The following measures are suitable, for example:

- Special equipment at sampling points to ensure that only small quantities can escape
- Use of dust suction systems
- Flexible wrapping of the transfer points of dusty products or products containing dust with dustproof materials

In the case of dusts, organizational measures, e.g., regular cleaning, can reduce dust layers, zone expansion, and the likelihood of a potentially explosive atmosphere occurring.

Ventilation measures are intended to prevent or restrict the formation of hazardous potentially explosive atmospheres as far as possible.

In the case of dusts, ventilation measures generally provide adequate protection only if the dust is extracted at the point of origin and hazardous dust layers are reliably prevented.

If an exit point of combustible dusts from a plant part is known (ventilation and feed openings, etc.), then the escaping substances can be specifically detected and discharged, e.g., through suction-cleaning of rims of open containers.

The suction system must be designed according to the specific parameters of the substances to be detected, the conditions determined by the plant and process, and the operating conditions. Possible faults must be taken into account. If no special technical measures are taken, the detection of combustible dusts will be confined to the immediate vicinity of the dust suction system.

Measures to Counteract Dust Layers in Dust-Laden Plants, Plant Parts, and Containers

Dust layers in the vicinity of dust-carrying plant parts and containers must be avoided wherever possible. If dust layers still occur, they must be removed regularly.

Work areas and operating rooms must be cleaned regularly. To this end, appropriate cleaning schedules can be drawn up, for example, which set out a binding framework for the type, scope, and frequency of cleaning measures and respective responsibilities for these measures. The specifications must be adapted to the individual circumstances in individual cases.

Particular attention must be paid to surfaces that are not easy to see, e.g., surfaces that are higher or that are otherwise difficult to access. Significant amounts of dust can accumulate on these surfaces over time. In addition, precautions must be taken to prepare for the eventuality that malfunctions caused by damage to or the bursting of containers, or by leakages, could result in a sudden large release of dust. In this case, it must be possible to remove such larger layers of dust immediately.

Safely Removing Dust

Zone Classification

Classification of Dust Hazardous Areas into Zones

In explosion protection, the procedures have been developed into different solution approaches, based on national regulations and laws. Today, we can distinguish between the IEC approach and the North American approach.

The solution approaches differ in the following ways:

- Classification of hazardous areas, in North America and Canada: "Hazardous (Classified) Locations"
- Design of the equipment
- Installation technology of electrical installations

In Europe, hazardous areas are divided into zones. This classification is described in IEC/EN 60079-10. Any area where combustible gases or swirling dusts are likely to be present must be categorized into one of the following 3 zones.

Zone 20

Zone	Definition	Example
Zone 20	Area in which a potentially explosive atmosphere in the form of a cloud of combustible dust is present in the air, permanently, over a long-term period, or frequently.	In general, the inside of containers, apparatus, and rigid conduits. It must be checked whether a dust hazardous mixture with air is present in the apparatus or rigid conduit concerned for a period of time and whether this mixture fills the apparatus or the rigid conduit completely or only partially. Examples of Zone 20 include the following interiors: ■ Crushing plant, mixing plant, and separation plant ■ Mills ■ Silos, bunkers with frequent filling operations ■ Product separators ■ Convection dryers ■ Fluidized bed granulators ■ Pneumatic conveyors

Zone 21

Zone	Definition	Example
Zone 21	An area in which a potentially explosive atmosphere in the form of a cloud of combustible dust in the air is expected to occur occasionally during normal operation.	Immediate vicinity of feed openings, the immediate area around filling devices and draining devices, and areas where dust layers are present that occasionally create a hazardous potentially explosive atmosphere as a result of dispersion. Areas inside plant, e.g., silos and mixers Areas in the immediate vicinity of plant, e.g., dust extraction points or filling stations Areas in which deposited dust is present in such a large quantity that hazardous explosive dust/air mixtures can occasionally be dispersed during normal operation

Zone 22

Zone	Definition	Example
Zone 22	Areas in the vicinity of dust-containing apparatus if dust only escapes in a nonexplosive concentration and only forms longer-term dust layers that can only briefly be dispersed to create hazardous potentially explosive dust/air mixtures.	Areas in the vicinity of dust-containing plant in which dust can escape through leaks and dust layers can build up.

If there is any doubt about the classification into zones, the scope of protective measures throughout the potentially explosive area must be based on the highest possible probability that a hazardous potentially explosive atmosphere will occur. Therefore, when hybrid mixtures occur in which dusts can combine with gases, vapors, or mists to form a hazardous potentially explosive atmosphere, the classification of the hazardous area according to Zones 0, 1, and 2 and Zones 20, 21, and 22 must be considered.

Appropriate measures can reduce the likelihood of a potentially explosive atmosphere occurring. This must be taken into account in the zone classification.

In practical implementation, relevant national regulations for zone classification, installation, and operation of the plant are to be observed at the plant operating location. These may differ from or further substantiate IEC regulations.

Protective Measures

Zone 20

In Zone 20, the temperature of surfaces that may come into contact with a dust cloud must never exceed two thirds of the minimum ignition temperature (°C) for the dust cloud concerned. This must not happen even in the event of rare malfunctions. For safety reasons, the temperature of surfaces on which dust may be deposited must be lower by a given safety margin than the minimum ignition temperature of the thickest layer that may form from the dust in question. This must be guaranteed, even in the event of rare malfunctions. If the layer thickness is unknown, the thickest layer predictable must be assumed.

Zone 21

In Zone 21, the temperature of surfaces that may come into contact with a dust cloud must never exceed two thirds of the minimum ignition temperature (°C) for the dust cloud concerned. This must not happen even in the event of malfunctions. For safety reasons, the temperature of surfaces on which dust may be deposited must be lower by a given safety margin than the minimum ignition temperature of the thickest layer that may form from the dust in question.
This must be guaranteed, even in the event of malfunctions.

Zone 22

In Zone 22, the temperature of surfaces that may come into contact with a dust cloud must never exceed two thirds of the minimum ignition temperature (°C) for the dust cloud concerned during normal operation. For safety reasons, the temperature of surfaces on which dust may be deposited must be lower by a given safety margin than the minimum ignition temperature of the thickest layer that may form from the dust in question.

Types of Protection

Basic ignition protection methods help reduce the risk of an explosion.

Ignition Protection Method 1: Prevention of Effective Ignition Source

This method can offer the following possibilities for explosion protection in dust environments:

- Limitation of thermal effects such as hot surfaces
- Prevention of electrical or mechanical sparks
- Limiting the electrical energy of a spark to a safe level even under certain fault conditions. This corresponds to the intrinsic safety type of protection.

Ignition Protection Method 2: Spatial Separation of Ignition Source and Explosive Atmosphere

With this method, possible ignition sources such as electrical components and hot surfaces are spatially separated from the explosive mixture.

The type of protection Ex p and type of protection Ex m are based on this method.

Selecting a Suitable Type of Protection and Possible Sources of Fault

The selection of the equipment protection level of a particular type of protection is dependent on the degree of safety that is required for the relevant hazardous area. The type of protection should guarantee that the lowest possible probability exists for the simultaneous presence of an effective ignition source and a hazardous, potentially explosive atmosphere.

Technical Marking

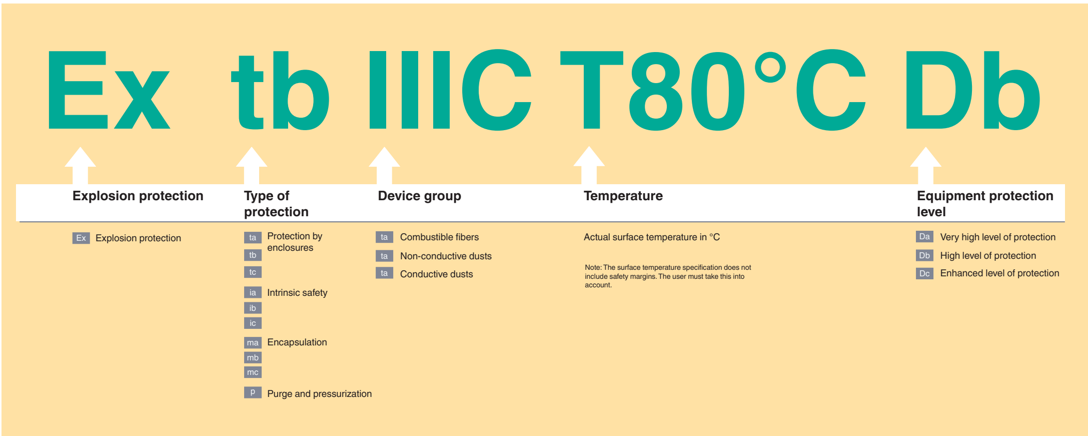


Figure 6.1 Technical marking according to IEC/EN 60079

Old Marking of Technical Apparatus

Explosion protection	Type of protection and, where applicable, degree of safety	Zone	Degree of protection	Surface temperature
Ex	tD	A21	IP67	T105 °C
Standards: Ex: International standards IEC 60079	**Type of protection:** pD: purge and pressurization iaD: intrinsic safety ibD: intrinsic safety mD: equipment protection by encapsulation "m" tD: protection by enclosure	**Zone:** 20 21 22 **Special features:** Differentiation between methods A and B for tD A21 B22	**Degree of protection:** IPXY	**Temperature:** Maximum surface temperature in °C

Type of Protection Ex t

Device Dust Explosion Protection by Enclosure "t"

Type of protection according to IEC/EN 60079-31, formerly "tD" according to IEC 61241-1, is a special type of protection for dust hazardous environments. To fulfill this type of protection, the electrical device has an enclosure with protection against dust ingress and precautions for limiting the surface temperature.

Devices with this type of protection can be used as apparatus for equipment categories 1D (Zone 20), 2D (Zone 21), and 3D (Zone 22).

Devices of the type of protection "t" are protected by the level of protection "ta" (EPL "Da"), or "tb" (EPL "Db"), or "tc" (EPL "Dc").

- For devices of the type of protection "ta," the maximum permitted short circuit current of the current source must be cited in the marking.
- For the level of protection "ta," the entire surface of the enclosure must undergo thermal examination with a dust dumping that is at least 200 mm thick.

The devices must be protected against dust ingress and satisfy the following requirements:

Type of Protection "t": Level of Protection According to Equipment Group

Level of protection	IIIC	IIIB	IIIA
ta	IP6X	IP6X	IP6X
tb	IP6X	IP6X	IP5X
tc	IP6X	IP5X	IP5X

Functional Principle of the Type of Protection Ex t

Devices with this type of protection have a special enclosure that prevents the ingress of dust. The enclosure must be engineered in a way that a maximum surface temperature can never be exceeded.

Devices with this type of protection can be used as apparatus for equipment categories 1D (Zone 20), 2D (Zone 21), and 3D (Zone 22).

Type of Protection "Equipment Dust Protection by Enclosure"

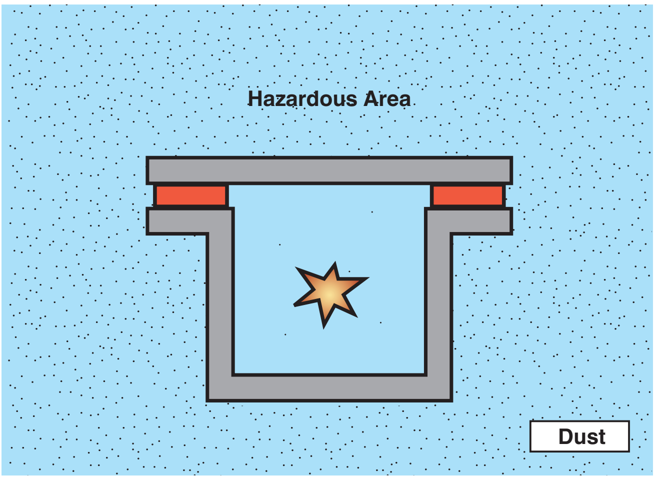


Figure 6.2 Schematic diagram of equipment dust protection by enclosure (IEC 60079–31, EN 60079–31 and UL 60079–31)

Main Applications and Marking

- Lights
- Sensors and actuators

Marking (Old)

Ex II 2 D EEx tD A21 IP65 T80 °C

Marking since 2009

Introduction of the equipment protection level (EPL) and the explosion subgroups for all types of protection due to electrostatics.
Explosion group according to IEC: II: Gas, III: Dust

Ex II 2 D Ex tb IIIC T80 °C Gb IP65

Type of Protection Ex i – Intrinsic Safety

Type of Protection Intrinsic Safety "i"

Type of protection according to IEC/EN 60079-11, formerly "iD" according to IEC 61241-11. This type of protection is based on limiting the electrical energy to a defined value. This value lies below the limit value that can trigger an ignition by spark generation or thermal effect. These parameters apply within the devices and for all connecting cables that are exposed to a potentially explosive atmosphere.

Devices with this type of protection can be used as apparatus for equipment categories 1D (Zone 20), 2D (Zone 21), and 3D (Zone 22).

Devices of the type of protection "i" are protected by the level of protection "ia" (EPL "Da"), or "ib" (EPL "Db"), or "ic" (EPL "Dc").

The type of protection "i" does not refer to an individual apparatus but to the entire intrinsically safe circuit.

In intrinsically safe circuits, the spark energy and thermal effects required to ignite a potentially explosive atmosphere do not occur. This is achieved by limiting the current, voltage, and power in the supply unit, i.e., the associated apparatus. Energy storage present in the circuit, such as inductances and capacitances, which occur in the field device, i.e., in the intrinsically safe apparatus, and in the connection line. Spark energies or thermal effects that can lead to the ignition of a potentially explosive atmosphere must not occur in normal operation or in the case of a fault.

Intrinsically safe circuits must be protected against coupling by external electrical or magnetic fields. This can be achieved with suitable cables and by maintaining an appropriate distance or by using shields or twisted cores.

Evidence of this must be documented in the explosion protection document for the plant.

Operating Principle of the Type of Protection Ex i

Currents and voltages are safely limited in intrinsically safe circuits, and power and heat factors are taken into account.

The energy storage is limited safely, e.g., coils and capacitors. This takes into account distributed electrical reactance values of cables.

A typical configuration includes the following two components:

- An associated apparatus (or "barrier") that limits the energy reaching the hazardous area
- An apparatus (or "device") that is structurally restricted to fulfill the type of protection

Type of Protection "Intrinsic Safety"

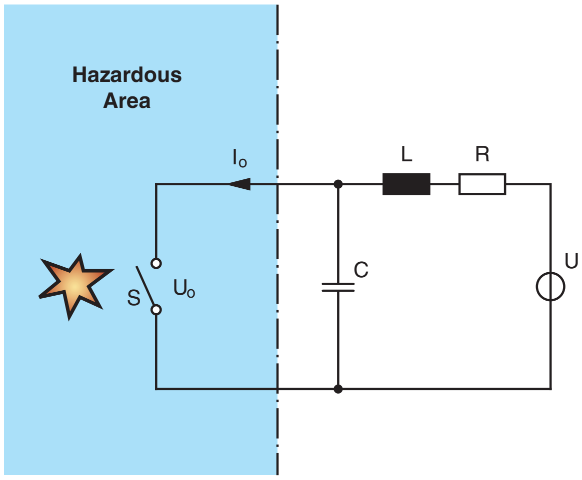


Figure 6.3 Schematic representation of an intrinsically safe circuit (IEC 60079–1, EN 60079–1, and UL 60079–1)

The user undertakes the verification of intrinsic safety and documents this verification in the plant documentation. In accordance with IEC/EN 60079-14:2013 (Sections 4.2 and 16.2.4), NEC Article 504, and CEC Section 18, verification is required as part of the plant documentation, which must be available in the plant. In Germany, this must take place in accordance with § 6(9) of the German Hazardous Substances Ordinance in the explosion protection document. Most commonly, this is done as part of or appendix of the apparatus list.

Intrinsically safe circuits must be protected from any kind of coupling. To achieve this, minimum distances are observed on the terminals, for example 50 mm from intrinsically safe terminals to non-intrinsically safe terminals.

Cables must be marked and protected.

Main Applications and Marking

- Measurement and control engineering
- Sensors and actuators
- Instrumentation

Marking (Old)

Ex II 1 D EEx ia D 20 IP67 T60 °C

Marking since 2009

Introduction of the equipment protection level (EPL) and the explosion subgroups for all types of protection due to electrostatics.

Ex II 1 D Ex ia IIIC T80 °C Ga

Type of Protection Ex p

Type of Protection Purge and Pressurization "p"

Protection technology in accordance with IEC/EN 60079-2 against the ingress of an ambient atmosphere into an enclosure where the enclosure contains a protective gas against the surrounding atmosphere under overpressure.

The type of protection purge and pressurization "p" is subdivided into three levels of protection: "px," "py," and "pz."

An equipment protection level (EPL) is assigned to every level of protection. This EPL is based on the likelihood of the device becoming an ignition source in a potentially explosive atmosphere.

Level of protection	Equipment category Dust	Degree of safety
px	2D	Installation of the device in Zone 21: no explosion hazard in interior. Use of standard devices safe.
py	3D	Installation of the device in Zone 21: interior of the device in Zone 22. Safe use of Zone 22 and EPL Dc devices.
pz	3D	Installation of the device in Zone 22: no explosion hazard in interior. Use of standard devices safe.

Tabelle 6.1 Levels of protection for the type of protection "purge and pressurization (Ex p)" in dust hazardous areas

In this type of protection, an automatic appliance must be provided to shut down the electrical power supply to the device and to trigger an audible or visible alarm if the overpressure or throughflow of the protective gas falls below the prescribed minimum value.

If the internal pressure or the throughflow of the protective gas falls below the specified minimum value, the pressure loss must be indicated by a signal that is immediately visible to the operating personnel. The pressurization system must be repaired as quickly as possible, or otherwise be switched off manually.

Purging of the purge and pressurization for dust is not permitted. Before switching on the device power supply, when starting up, and after shutting down, it must be checked that no dust has entered the enclosure or the associated conduits at a concentration that is likely to create a potential dust hazard.

Doors and covers that can be opened without tools must be locked such that, when opened, the power supply is automatically switched off for all parts that are not otherwise protected. It is essential to prevent the power supply from being switched on before the doors and covers are closed again.

Functional Principle of the Type of Protection Ex p

The potential ignition sources are located in a robust enclosure under a low overpressure: 25 Pa … 50 Pa, or 0.25 mbar … 0.5 mbar. If air is used as a protective gas, this air must be drawn from the non-hazardous area.

Type of Protection "Purge and Pressurization"

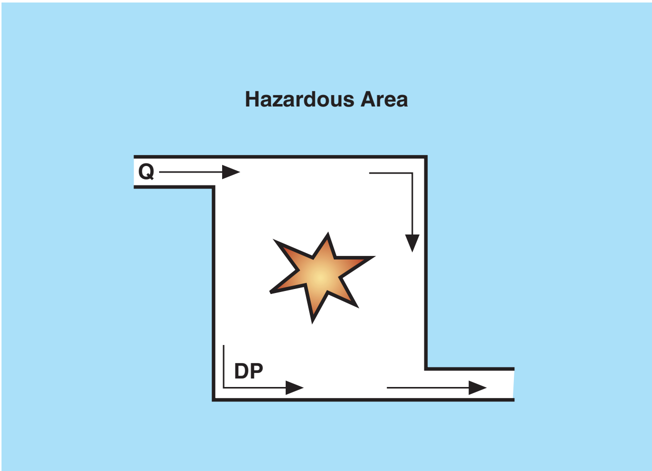


Figure 6.4 Schematic diagram of a pressurizing system (IEC 60079–2, EN 60079–2, FM 3620 and NFPA 496)

Main Applications and Marking

- Switch cabinets
- Large motors
- Measuring instruments and analysis equipment

Marking (Old)

Ⓔx II 2 D EEx pD 21 IP65 T60 °C

Marking since 2009

Introduction of the equipment protection level (EPL) and the explosion subgroups for all types of protection due to electrostatics.
Explosion group according to IEC: II: Gas, III: Dust.

Ⓔx II 2 D Ex pxb IIIB T60 °C Gb

Type of Protection Ex m: Protection by Encapsulation

Type of Protection Equipment Protection by Encapsulation "m"

The type of protection "m" in accordance with IEC/EN 60079-18, formerly "mD" in accordance with IEC 61241-18, prevents the ignition of a surrounding potentially explosive dust atmosphere under operating or installation conditions by including ignitable parts in a casting compound and thus preventing spark generation or heating.

Devices of the type of protection "m" are protected by the level of protection "ma" (EPL "Da"), or "mb" (EPL "Db"), or "mc" (EPL "Dc").

An equipment protection level (EPL) is assigned to every level of protection. This EPL is based on the likelihood of the device becoming an ignition source in a potentially explosive atmosphere.

The potential ignition sources are located in the enclosure. The potentially explosive atmosphere is prevented from entering the enclosure.

The enclosure has sufficient mechanical strength and is chemically protected against the materials in which it is to be used. The filling material must not come away from the enclosure wall in the event of permitted temperature fluctuations.

Functional Principle of the Type of Protection Ex m

The equipment protection by encapsulation "m" method prevents the potentially explosive atmosphere from penetrating into an enclosure with potential ignition sources.

Type of Protection "Equipment Protection by Encapsulation"

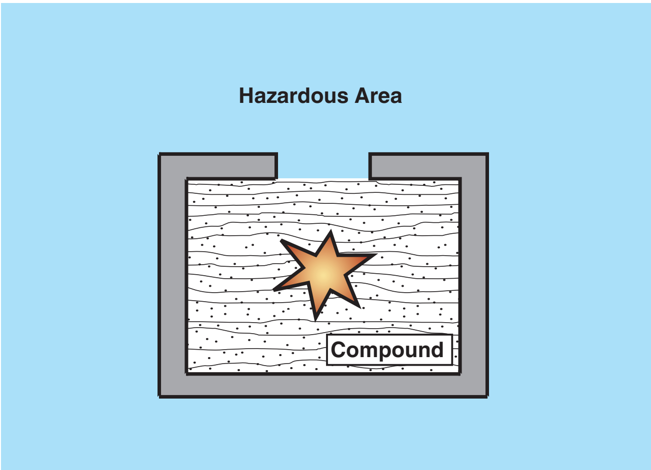


Figure 6.5 Schematic diagram of equipment protection by encapsulation (IEC 60079–18, EN 60079–18 and UL 60079–18)

The enclosure has sufficient mechanical strength and is chemically resistant to the materials in the vicinity of which it is to be used.

The filling material must not come away from the enclosure wall during permitted temperature fluctuations.

The user himself is responsible for following the manufacturer's instruction manual to install, bring into service, and operate the apparatus.

Main Applications and Marking

- Solenoid valves
- Sensors

Marking (Old)

II 2 D EEx mD 21 T 90 °C

Marking since 2009

Introduction of the equipment protection level (EPL) and the explosion subgroups for all types of protection due to electrostatics.
Explosion group according to IEC: II: Gas, III: Dust.

II 2 D Ex mb IIIC T90 °C Db

Installation

With careful planning of the electrical plant, many electrical devices can be installed in less hazardous or nonhazardous areas.

If electrical devices have to be installed in areas where explosive concentrations and quantities of ignitable dusts may be present in the atmosphere, targeted protective measures are applied. This minimizes the likelihood that an explosion will be triggered by the ignition of electric arcs, sparks, or hot surfaces that can occur during intended operation or under specified fault conditions.

Many types of dust that are generated, processed, and stored are combustible. If such dusts are mixed with air in the appropriate ratio, they can burn very quickly once ignited and can explode with considerable force.

Electrical devices often need to be operated in places where such combustible materials are present. Therefore, appropriate precautions must be taken to ensure that all these devices are adequately protected. This is the only way to reduce the likelihood of the external potentially explosive atmosphere being ignited. Possible ignition sources in electrical devices include electric arcs, electrical sparks, hot surfaces, and friction sparks.

Ignition by Electrical Devices

Combustible dust can be ignited by devices in a variety of ways:

- Ignition by the surface of the device at a temperature above the minimum ignition temperature for the dust concerned.
  The temperature at which dust ignites depends on various characteristics:
  - Dust types: What is the material and grain of the dust?
  - Form of dust: Is it a cloud or a deposit?
  - For dust layers: How thick is the dust layer?
  - Environment: What are the dimensions and form of the heat source?
- Ignition by electric arcs or sparks from electrical parts such as switches, contacts, commutators, brushes, etc.
- Ignition by discharging a stored electrostatic charge
- Ignition by radiation energy, e.g., by electromagnetic radiation
- Sparks caused by impact effect or friction generated by the device

Measures to Avoid Ignition Hazards Caused by Electrical Devices

To avoid ignition hazards in the event of dust, the following precautions, among others, must be taken.

- Keep the temperature of surfaces on which dust can accumulate or that may come into contact with a dust layer within specified temperature limits.
- Check electrically sparking parts in one of the following ways:
  - Include parts in an enclosure that adequately prevents dust ingress
  - Limit the energy of the electrical circuits of these parts to avoid electric arcs, sparks, or temperatures that could ignite combustible dust.
- Avoid all other ignition sources.

Equipment Protection Level "EPL"

The equipment protection level (EPL) is the level of protection specified for a device. This is based on the level of probability of ignition. Differences between potentially explosive gas atmospheres, potentially explosive dust atmospheres, and potentially explosive atmospheres in firedamp-sensitive mines are taken into account. For potentially explosive dust atmospheres, the following EPLs apply:

- EPL "Da"
  Device with a very high equipment protection level. The device can be used in hazardous areas without presenting an ignition hazard in normal operation, in the event of foreseeable or rare faults, or in the case of failures.
- EPL "Db"
  Device with high level of protection. The device can be used in hazardous areas without presenting an ignition hazard in normal operation, in the event of foreseeable faults, or in the case of failures.
- EPL "Dc"
  Device with extended level of protection. The device can be used in hazardous areas without presenting an ignition hazard during normal operation. The device includes some additional protective measures to ensure that there is no ignition hazard in the event of typically foreseeable malfunctions of the device, e.g., in the event of a failure of the electric light source.

Selection of Devices According to EPL

The conformity of devices must be checked for new plant or when using the devices.

If only zones are specified in the hazard assessment documentation, the relationship between equipment protection levels (EPLs) and zones must be established in accordance with the following table.

Zone	EPL
20	Da
21	Da or Db
22	Da, Db, or Dc

The recognized types of protection of IEC standards have been assigned to the EPLs. This means that if the device is marked with the corresponding EPL, or uses the corresponding type of protection, it can be used with the EPL defined as required for the operating location.

IEC Types of Protection and EPL Assignment

Device type of protection	Device EPL/EPL requirement at operating location
ia ma ta	Da
ib mb tb tD pD	Db
ic mc tc tD pD	Dc

Selection of Devices According to Equipment Group

The equipment groups that are permissible for use depend on the types of dust present at the operating location.

Type of dust at the operating location	Permitted equipment group
IIIA (combustible flyings)	IIIA, IIIB, or IIIC
IIIB (nonconductive dust)	IIIB or IIIC
IIIC (conductive dust)	IIIC

Selection of Devices According to the Ignition Temperature of the Dust

The electrical device must be selected so that its maximum surface temperature does not reach the ignition temperature of the dust present. If no ambient temperature range is specified in the marking on the electrical device, the device is suitable for use in the temperature range of -20 °C … +40 °C. If an ambient temperature range is specified in the marking, it is valid for the device.

Dust layers demonstrate two properties as the layer thickness increases:

- Decrease in the minimum ignition temperature
- Increase in thermal insulation

The maximum permissible surface temperature of the device is determined by deducting a safety margin from the minimum ignition temperature of the dust concerned. The surface temperature is tested according to the methods for dust clouds and dust layers defined in IEC 61241-2-1.

Temperature Limit for Dust Clouds

The maximum permissible surface temperature of the device must not exceed two thirds of the minimum ignition temperature in degrees Celsius for the dust/air mixture concerned.

$T_{max} \leq 2/3\ T_{CL}$; T_{CL} = minimum ignition temperature of the dust cloud

Temperature Limit for Dust Layers

Layer thickness ≤ 5 mm

The maximum surface temperature of the device must not exceed a value of 75 °C below the minimum ignition temperature for a layer thickness of the dust concerned of 5 mm:

$T_{max} \leq T_{5\,mm}$ - 75 °C; $T_{5\,mm}$ = minimum ignition temperature for the dust layer (smolder temperature) of 5 mm

Layer thickness > 5 mm … ≤ 50 mm

Where dust layers of more than 5 mm may accumulate on devices, the maximum permissible surface temperature must be reduced. The following diagram shows examples of how the maximum permissible surface temperature for devices used in the presence of dust with increasing layer thicknesses can be reduced for a layer thickness of 5 mm at a smolder temperature in excess of 250 °C:

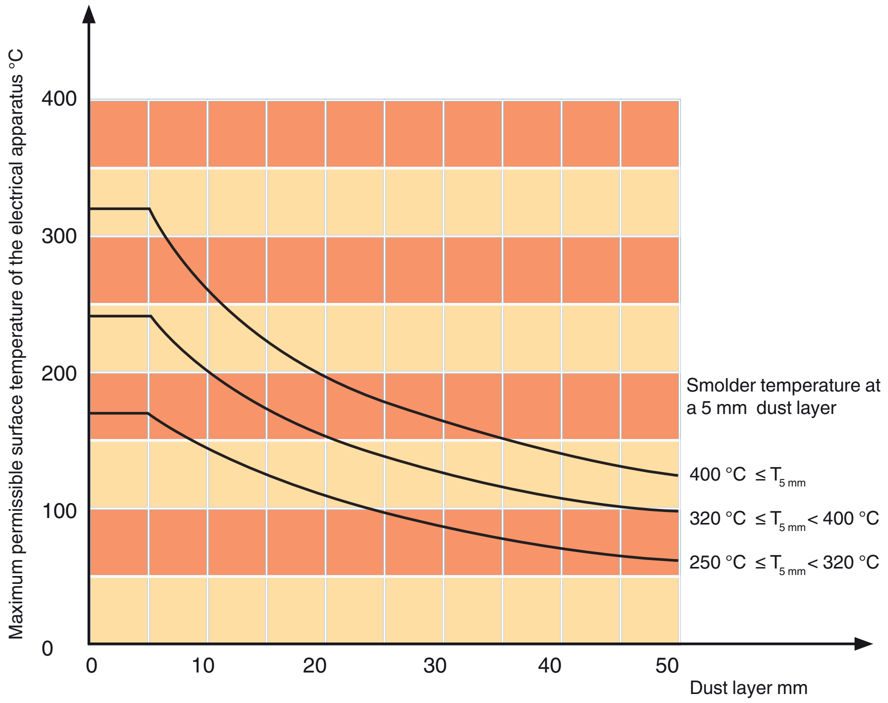


Figure 7.1 Correlation of maximum permissible surface temperature and thickness of the dust layer

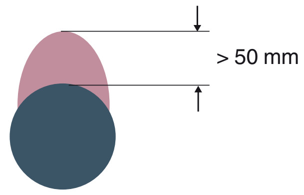
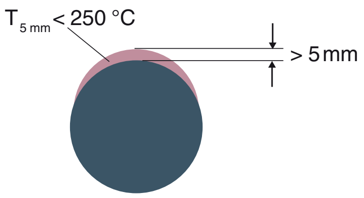
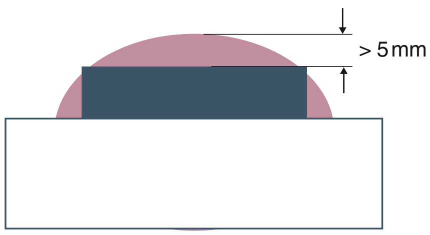
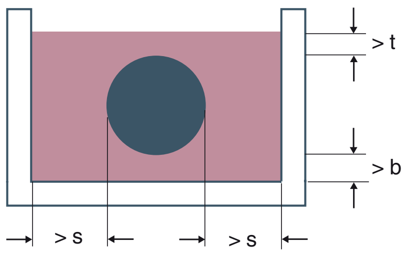
Laboratory verification must be provided for equipment where the ignition temperature for a dust layer of 5 mm is below 250 °C, or where there is doubt as to the application of the diagram.

Layer thickness > 50 mm

Due to the thermal insulation effect, a much lower surface temperature may be necessary under the following conditions:

- It is not possible to avoid a dust layer forming around the sides and underneath the bottom of a device.
- The device is completely covered in dust.

Types and Limit Values for Dust Deposits

	**Figure M.1a** Excessive dust layers on top of the device housing.
	**Figure M.1b** Excessive dust layers on top of the device housing with the dust having a low ignition temperature.
	**Figure M.1c** Excessive dust layers on both sides of the device housing.
	**Figure M.1d** Fully dust covered device. Limit values for the measures b, s and t are to be determined by laboratory tests.

For plant where the layer thickness exceeds 50 mm, the maximum surface temperature of the devices can be marked with the maximum surface temperature T_L as an indication of the permissible layer thickness.

If the device is marked with T_L for a layer thickness, the ignition temperature of the combustible dust at layer thickness L rather than $T_{5\,mm}$ must be applied. The maximum surface temperature T_L of the device must be at least 75 °C below the ignition temperature of the combustible dust at layer thickness L.

Plugs and Power Sockets

Power sockets in areas requiring EPLs "Db" and "Dc" must be installed such that no ingress of dust is possible either with or without plugs inserted. Power sockets must be arranged to keep the ingress of dust as low as possible in the event that the dust protection cover has inadvertently been left off: The power sockets must be placed at an angle not less than 60° from the vertical plane, with the opening facing downward.

When using connectors in potentially explosive dust atmospheres, make sure that no dust enters the connector when it is disconnected.

Accumulation of Combustible Dust

Cable glands must be arranged such that the minimum amount of dust accumulates and the cable glands are accessible for cleaning. If you are using ducts, channels, tubes, or trenches to collect cables, precautions must be taken in such locations to prevent the passage or accumulation of combustible dust. Where dust layers that will impair free air circulation easily form on cables, consider whether the current-carrying capacity should be reduced. This is particularly the case when dusts with a low minimum ignition temperature are involved.

Rotating Electric Machines

Type of protection "pD": motors with electrical drive inverter supply

Motors powered with variable frequency and voltage from an electrical drive inverter must meet one of the following requirements:

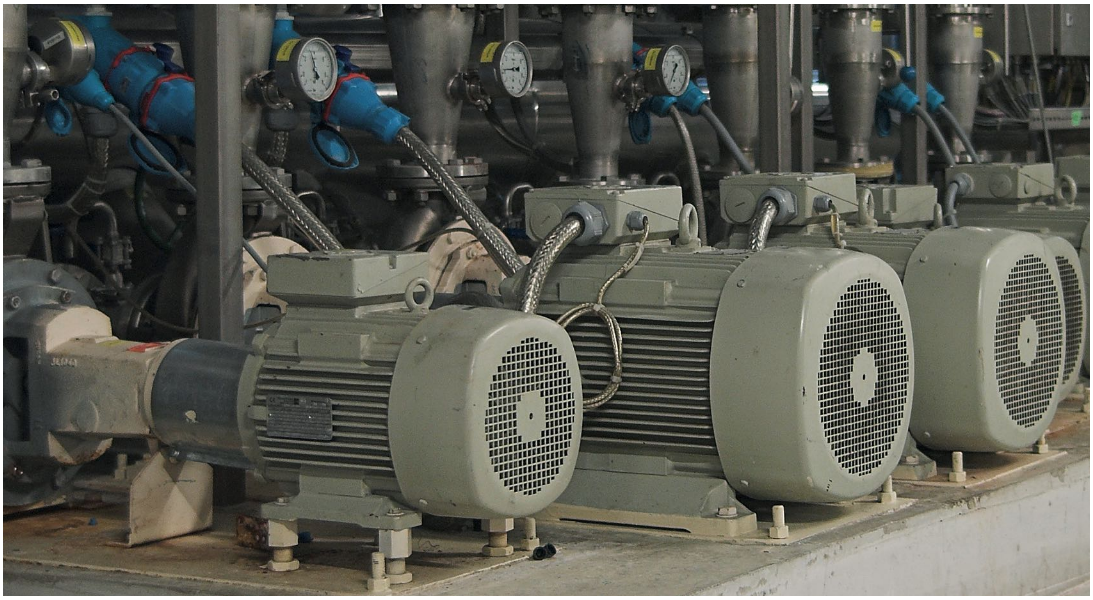
- The motor has been type-tested for this operating mode together with the designated protective equipment as a unit with the electrical drive inverter and with the designated protective equipment.
- The motor has not been type-tested for this operating mode as a unit together with the electrical drive inverter. In this case, measures must be taken to limit the surface temperature of the motor housing, e.g.:
    - Direct temperature monitoring by embedded temperature probes according to the documentation for the motor
    - Other effective action

Type of protection "t": protection by enclosure powered with variable frequency

Motors of type of protection Ex "t" that are powered with variable frequency and variable voltage must meet one of the following requirements:

- For this operating mode, the motor must be type-tested with the designated protective equipment as a unit with the electrical drive inverter specified in the documentation and with the designated protective devices.
- An embedded temperature probe for direct temperature monitoring according to the motor documentation should be present. Alternatively, precautions should be taken to limit the surface temperature of the motor housing. The protective equipment must trigger the electrical disconnection of the motor. The connection between the motor and the electrical drive inverter does not need to be checked together.

Motors in the Plant



Static Electricity

Avoid electrostatic charging of the construction and protective parts in operating locations requiring the EPLs "Da," "Db," and "Dc"

Painted or coated metal and plastic constructions and protective parts must be designed such that the risk of ignition from propagating brush discharges is avoided under proper conditions of use.

If plastic with a surface of more than 500 mm^2 is used on a conductive material, the plastic must have one or more of the following characteristics:

- The selected material must have a surface resistance that corresponds to the limits according to IEC/EN 60079-0.
- The breakdown voltage must be $\leq$ 4 kV.
- Devices and protective parts can be operated in the plant such that the risk of electrostatic discharge is minimized. In this case, the devices and protective parts must be provided with a warning label with the following wording:
  Warning—potential electrostatic charging hazard. (EN 67900-0, Table 18)
- Cable glands must be arranged so that they are not subject to friction effects and electrostatic charges when pulled through dust. Electrostatic charging of cables and lead surfaces must be avoided.

The material compositions of metallic installation materials (e.g., cable racks, mounting bases, weather protection) must meet specific requirements. Materials used in Group III installations for the designated equipment protection level must not contain more than the following elements in total:

- EPL "Da": A total of 7.5 % magnesium, titanium, zirconium
- EPL "Db": A total of 7.5 % magnesium, titanium, zirconium
- EPL "Dc": No specific requirements

Verification of Intrinsic Safety

DIN EN 60079-14 requires verification of intrinsic safety before commissioning an intrinsically safe circuit. At this point, commissioning of the overall plant is imminent and errors cannot be corrected promptly. It is therefore recommended that this calculation be carried out in the planning phase. This will also ensure that the required documentation is available in the form of an EU declaration of conformity, an instruction manual, and, if necessary, an EU type-examination certificate.

In an intrinsically safe circuit, neither a spark nor a thermal effect may cause ignition of a potentially explosive dust atmosphere.
It must never happen either in normal operation, or taking into account possible faults in the equipment or in the entire circuit itself.

The objective of intrinsic safety is achieved by limiting the current, voltage, and power in the supply unit. Inductances and capacitances form energy storage in the circuit. Such energy storage can increase the energy of any resulting spark and thus the risk of ignition. Energy storage must therefore be taken into account. The physical aspect of intrinsic safety is thereby created by limiting the following variables:

- Voltage U
- Current I
- Power P
- Inductance L
- Capacitance C

The functional aspect describes the classification of equipment and circuits in the following levels of protection:

- Ex ia
- Ex ib
- Ex ic, formerly Ex nL

These levels of protection describe the fault tolerance within which a circuit still remains intrinsically safe.

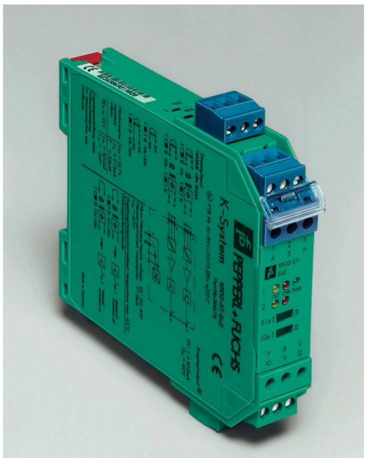
Basic Structure of Simple Circuits

In the simplest case, an intrinsically safe circuit consists of a supply unit as source, a field device as a consumer, and a cordset. Voltage U, current I, and power P are determined by the supply unit, but inductance L and capacitance C are determined primarily by the field device and the line.

Binary Isolated Switch Amplifier

Isolating amplifier with intrinsically safe control circuit:

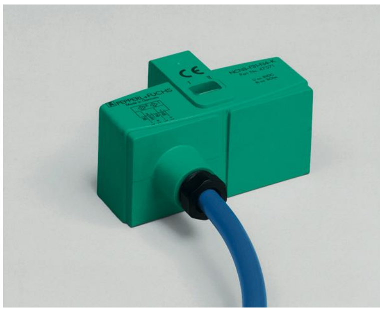
- Output voltage, max. $U_o = 12.7$ V
- Output current, max. $I_o = 17.3$ mA
- Output power, max. $P_o = 55$ mW



Proximity Sensor

Intrinsically safe inductive proximity sensor:

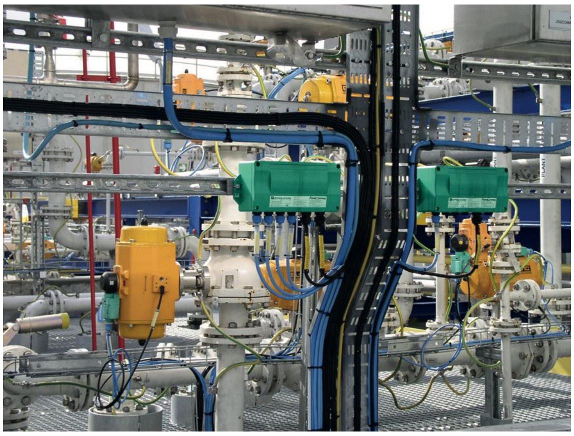
- Inner inductance $L_i = 100$ µH
- Inner capacitance $C_i = 100$ nF



Rigid Conduits

Installing intrinsically safe and other cables:

- Risk of electromagnetic coupling
- Risk of mechanical damage and galvanic coupling



DIN EN 60079-14 describes a calculation-based verification procedure based on the characteristic values described, namely voltage U, current I, power P, inductance L, and capacitance C. Mark the values that describe the associated apparatus with the index "o" for "out." Values that describe the intrinsically safe apparatus are supplemented with "i" for "in."

Associated apparatus	Intrinsically safe apparatus
$U_o \leq$	U_i
$I_o \leq$	I_i
$P_o \leq$	P_i

Associated apparatus	Cable	Intrinsically safe apparatus
$L_o \geq$	L_c	$+ L_i$
$C_o \geq$	C_c	$+ C_i$

Specification "U_o = 24 V" means that even taking into account possible component faults (see levels of protection ia, ib, and ic), the maximum voltage at the output terminals of the associated apparatus is 24 V. "P_i = 360 mW" for intrinsically safe apparatus indicates that a maximum power output of 360 mW is permissible to ensure compliance with the specified temperature class, for example.

The specifications L_o and C_o for an associated apparatus are particularly important. U_o, I_o, and P_o indicate that no ignitable sparks occur at the output terminals, even under fault conditions. L_o and C_o indicate which additional energy storages can be connected for the circuit to remain intrinsically safe. Since the energy storages are located in the field device and in the line, the verification needs to take account of the respective dimensions. This results in the basic method of calculation as follows:

The corresponding values can be found on the EU type-examination certificates for the associated and intrinsically safe apparatus. If it is a current certificate, the values are easy to determine, since the manufacturer of the supply unit will have indicated the maximum connectible capacitances and inductances for dusts of subdivisions IIIA, IIIB, IIIC, and these can be copied to the table.

Signal converter supply Connector pin: 2/3 ... 4/5			
Max. output voltage	U_oDc		24.9 V
Max. output current	I_o		77 mA
Max. output power	P_o		478 mW
Max. external capacitance	C_o	IIC IIB IIA IIIC	112 nF 850 nF 3.01 µF 850 nF
Max. external inductance	L_o	IIC IIB IIA IIIC	5.9 mH 23.9 mH 47.9 mH 23.9 mH
Max. inductance/ resistance ratio	L_o/R_o	IIC IIB IIA IIIC	74.1 µH/Ω 296.7 µH/Ω 593.4 µH/Ω 296.7 µH/Ω

This is not the case with older EU type-examination certificates. Only the values for gases IIA, IIB, and IIC are specified on the EU type-examination certificate for the associated apparatus. However, what should be done if, for example, the isolated switch amplifier only outputs these values?

The following statement about this is made in device standard DIN EN 60079-11:

"For Group III, the spark ignition tests to the requirements of Group IIB shall be applied to circuits exposed to dust.” (EN 67900-11, 5.5)
For those persons having to provide verification of intrinsic safety, this means that they can use the values for IIB gases.

The current signal converter power supply certificate also makes it easy to see that the IIB and IIC values are identical.

Documentation

To install a new plant correctly or upgrade an existing one, the following information about the plant, the devices used, the installation process, and the personnel is required.

Plant

- Documents for zone classification: plans for the classification and expansion of hazardous areas and zone classification with specification of the maximum permissible thickness of the dust layer
- Evaluation of the consequences of an ignition (optional)
- Classification of dust into a group or subdivision of electrical equipment (where applicable)
- Material characteristics (where applicable), e. g.:
  - Electrical resistance
  - Minimum ignition temperature for the cloud of combustible dust
  - Minimum ignition temperature for the combustible dust layer
  - Minimum ignition energy for the cloud of combustible dust
- External influences and ambient temperature

Devices

- Manufacturer's instructions for selection, installation, and initial test
- Documents for electrical devices with special conditions, e.g., devices with certificate numbers with the suffix "X"
- System description for the intrinsically safe system
- Details of all relevant calculations, e.g., purge rates for measuring instruments or analyzer housings
- Declaration from the manufacturer or the qualified person
- Information about maintenance

Installation

- Information required to ensure correct installation of devices
- Documentation on the suitability of the device for the area and environment to which it is to be exposed; e. g., rated temperature values, type of protection, degree of protection (IP), corrosion resistance
- Connection wiring diagrams
- Documentation of the selection criteria for cable glands with regard to compliance with the requirements for the type of protection
- Drawings and plans for circuit identification
- Records of the initial test

Personnel

- Evidence of the capability of the personnel

Testing and Maintenance

To fulfill their duties, employers and their officers need reliable sources that they can use as a basis for their work and for legal and technical procedures. Directive1999/92 EC is implemented into national law in Germany by the Ordinance on Industrial Safety and Health. The requirements of this directive are specified for the employer by the technical rules under the Ordinance on Industrial Safety and Health (TRBS).

In addition to the requirements of the respective manufacturers, technical sources include IEC/EN 60079-14: Explosive atmospheres: Electrical installations design, selection and erection and IEC/EN 60079-17: Explosive atmospheres: Electrical installations inspection and maintenance. Both standards are recognized worldwide as technical sources and are valuable aids, since their installation and test requirements have been tailored to the electrical ignition protection methods of secondary explosion protection standardized by IEC.

Maintenance Work in the Plant

Tests According to Manufacturer's Specifications

Each plant consists of a variety of components, devices, and modules. The employer must ensure the suitability of these components for the respective use and take into account the characteristics promised by the manufacturer in the context of its hazard assessments—including any restrictions such as typical characteristics guaranteed by the manufacturer in conjunction with explosion protection measures:

Primary explosion protection

1. Sealing materials
   - Material resistance based on pressure and temperature ranges
   - Corrosion behavior based on the application
   - Period of usability based on the application
2. Ventilation measures
   - Guaranteed quantities of air delivered

Secondary explosion protection

1. Sealing materials
   - Electrical conductivity to prevent electrostatic charge
2. Explosion-protected devices
   - Prevention of effective ignition sources

Design-driven explosion protection

1. Explosion pressure relief devices
   - Maintenance of promised response pressure of bursting disks
2. Explosion suppression devices
   - Limitation to reduced explosion pressure

The manufacturer can only guarantee the promised characteristics of its products while its devices are installed and operated correctly in accordance with the specifications of the respective instruction manual and tested and maintained according to the manufacturer's requirements. Instruction manuals, installation, test, and maintenance specifications of the respective manufacturers must therefore be used as a basis for the hazard assessment. The test plans must be drawn up from these specifications, taking into account the specific plant situation.

Implementation Responsibility for the Tests

The employer, or the representatives it has appointed, is responsible for carrying out the tests. Institutions, external companies or persons, or in-house personnel can be tasked with carrying out the tests. Depending on the test task, there are different requirements for the qualifications of persons carrying out the tests.

Qualifications of Persons Carrying out the Tests

In principle, only suitable and reliable persons may be used for test activities. If the employer commissions external companies or persons, a service contract or contract for work arises in which not only services are defined and demanded, but also the necessary qualifications of the persons performing the work are contractually defined. To this end, it can be based on IEC 60079-17, Annex B, in the context of electrical tests in hazardous areas.

If the employer commissions its own personnel with test tasks, IEC/EN 60079-17 serves as an important source of information regarding the specialist knowledge and expertise required. The employer must ensure in advance that the employee tasked with carrying out tests meets the requirements of the Ordinance on Industrial Safety and Health for the respective test activities in each case; see TRBS 1203. If the employer commissions an approved monitoring body for tests as part of explosion protection accredited by the competent regional authority, it can assume its specialist knowledge and expertise as a given and does not need to question it.

Initial Test

Prior to the operating phase, an initial test of the plant is essential. This test provides proof that the plant has been planned and installed such that compliance with the target states for intended operation and their permissible limit values is ensured. It is particularly important to check whether the requirements from the hazard assessment have been correctly implemented and that installations have been carried out right. The combination of explosion hazards and hazards from the electrical installation, such as hazardous leakage currents (e.g., also due to the presence of operating personnel) and effective ignition sources, present major risks to safe and economical plant operation.

In Germany, the test prior to initial commissioning includes the following two aspects:

- Confirmation of the right selection, mounting, installation, setup conditions, and safe functioning of all equipment that is to be used in hazardous areas or is required as associated apparatus for the safe functioning of this equipment
- Proof of explosion safety of the entire plant prior to the first use of the workplaces through a comprehensive examination. This test task is considerably more extensive and complex. As a holistic assessment of the plant, it goes far beyond consideration of the components and serves to prove the correctness of the entire explosion-protection concept.

The devices must be installed according to their documentation. It must be ensured that replaceable parts correspond to the correct type and the right dimensions. Following completion of installation and prior to initial use, a detailed initial test of the devices and their installation must be carried out in accordance with EN 60079-14:2014, Annex C. The test plans are based on IEC/EN 60079-17 for detailed tests.

Recurring Tests

During the operating phase, it is necessary to maintain safe plant operation with recurring tests. Recurring tests are used to detect and rectify deviations from an intended state of individual components or functional units, as well as to identify and rectify the state of the installation as early as possible. Such deviations may include:

- Damaged seals on conduit connections
  – Risk of substance release and leakages
- Damaged seals on explosion-protected equipment
  – Risk of activation of ignition sources
- Open equipotential bonding
  – Risk of electrostatic charges
- Missing cable glands
  – Risk of active ignition sources despite explosion-protected equipment design
- Damaged cable sheath/cable insulation
  – Risk of active ignition sources due to electrical sparks/arcs
- Insufficient bearing lubrication
  – Risk of active ignition sources due to hot surfaces
- Impermissible modifications to plant or conversions
  – Risk of release of substances and/or active ignition sources due to nonintended use
- Corrosion on tertiary pressure relief devices
  – Risk of uncontrolled release of explosion energy

Check after Modification of Plant

If essential safety features of an explosion-protected plant are modified, the plant must undergo an initial test like any new plant prior to recommissioning. The employer must determine which test requirements are created as a result of a modification to a plant as part of the hazard assessment. The scope of the Ordinance on Industrial Safety and Health is defined in the technical rule TRBS 1123: Changes to plant in hazardous areas requiring testing—determination of the requirement for testing according to § 15 paragraph 1 of the Ordinance on Industrial Safety and Health. TRBS 1123 specifies the Ordinance on Industrial Safety and Health in more detail with regard to identifying and evaluating hazards and deriving suitable measures.

Recurring Testing of Electrical Equipment in a Plant

Sources and References

Professional Association for Raw Materials and the Chemicals industry: Information Sheet R003 (formerly BGI 747): Identification and evaluation of safety parameters. 2014.

German Professional Association's Institute for Occupational Safety (ed.): Data sheet for the database of hazardous substances "GESTIS-Dust-EX": Combustion and explosion characteristics of dusts. 2001.

German Social Accident Insurance (DGUV) (ed.): DGUV rule 113-001 Explosion protection rules (EX-RL). Collection of technical rules for the avoidance of danger from potentially explosive atmospheres with a sample collection for the classification of hazardous areas into zones. 2018.

German Central Federation of Industrial Professional Associations (ed.): Report 12/97 from the German Professional Association's Institute for Occupational Safety: Combustion and explosion characteristics of dusts. 1997.

Technical Committee for Plant Safety (Technischer Ausschuss für Anlagensicherheit—TAA): TAA-GS 33: Guidelines for Explosive Dust/Air Mixtures and Major Accidents Ordinance (Leitfaden Explosionsfähige Staub-/Luft-Gemische und Störfallverordnung). April 2004.

DIN EN 1127-1: Explosive atmospheres – Explosion prevention and protection – Part 1: Basic concepts and methodology

DIN EN 60079-0 Explosive atmospheres – Part 0: Equipment – General requirements

DIN EN 60079-10-2 Explosive atmospheres—Part 10-2: Classification of areas—Explosive dust atmospheres

DIN EN 60079-11: Explosive atmospheres – Part 11: Equipment protection by intrinsic safety "i"

DIN EN 60079-14 Explosive atmospheres – Part 14: Electrical installations design, selection and erection

DIN EN 60079-17 Explosive atmospheres - Part 17: Electrical installations inspection and maintenance in hazardous areas.

DIN EN 60079-18 Explosive atmospheres – Part 18: Equipment protection by encapsulation "m"

DIN EN 60079-31 Explosive atmospheres – Part 31: Equipment dust ignition protection by enclosure "t"

DIN EN 61241-1 Electrical apparatus for use in the presence of combustible dust – Part 1: Protection by enclosures "tD"

DIN EN 61241-4 Electrical apparatus for use in the presence of combustible dust – Part 4: Type of protection "pD"

Information system on hazardous substances of the German Social Accident Insurance (GESTIS): http://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp

IEC 60079-31 Explosive atmospheres—Part 31: Equipment dust explosion protection by enclosure "t"

International Electrotechnical Vocabulary (IEV). Also published in the IEC 60050 series of standards. www.electropedia.org

Directive 1999/92/EC of the European Parliament and Council of December 16, 1999 regarding minimum provisions to improve health protection and safety of employees who may be endangered by potentially explosive atmospheres (Fifteenth Individual Directive for the Purpose of Article 16, Para. 1 of Directive 89/391/EEG)

Directive 94/9/EC of the European Parliament and the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres.

Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work

Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres.

TRBS 1123—Change and major modifications of plants (Änderung und wesentliche Veränderung von Anlagen)

German Federal Institute for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitssicherheit—BAuA): Technical regulations for safety in the workplace (Technische Regeln für Betriebssicherheit—TRBS 1201): Tests of work equipment and plant requiring monitoring (Germany) 2012.

TRBS 1203 - Qualified persons (Befähigte Personen)

Bundesanstalt für Arbeitsschutz und Arbeitssicherheit (BAuA): Technische Regel für Betriebssicherheit (TRBS 2152 Teil 3): Gefährliche explosionsfähige Atmosphäre - Vermeidung der Entzündung gefährlicher explosionsfähiger Atmosphäre. (Technical rules for operational safety [TRBS 2152 part 3]: Hazardous, potentially explosive atmospheres - Avoidance of igniting a potentially explosive atmosphere) Germany, 2009.

TRD 413—Coal dust firing systems on vapor boilers (Kohlenstaubfeuerung an Dampfkesseln)

TRD 415—Fluidized-bed combustion devices on vapor boilers (Wirbelschichtfeuerungen an Dampfkesseln)

VDI Directive 2263 Dust fires and dust explosions

VDI Directive 3673 Pressure release of dust explosions

Basic Brochures from Pepperl+Fuchs

Pepperl+Fuchs, ed., Physical-technical principles—Terminology definitions, explosions, examples, prerequisites, combustible substances and characteristic values, ignition sources.

Pepperl+Fuchs, ed., Types of protection for electrical apparatus—Types of protection for gas hazardous areas, functional principle, identification, specifics for use.

Pepperl+Fuchs editor, Nonelectrical explosion protection: Specifics of nonelectric devices, ignition hazard assessment, types of protection, marking.

Pepperl+Fuchs editor, Type of protection: intrinsic safety.

Pepperl+Fuchs, ed., Dust explosion protection—Types of protection for dust hazardous areas, specifics of combustible dust, functional principle, identification, specifics for use.

Pepperl+Fuchs editor, IEC/EN 60079-14 - Explosive atmospheres - Part 14: Electrical installations design, selection and erection.

Pepperl+Fuchs editor, Global specifications and directives—Laws and regulations of regions or countries for the placing on the market of explosion-protected equipment.

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