The basics of explosion protection

STAHL

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preface

It is a fact that gases, vapours and mists escape during the production, processing, transportation, and storage of flammable substances in the chemical and petrochemical industries, as well as during the production of mineral oil and natural gas, in mining and in many other sectors. During many processes, especially in the food industries, combustible dusts are also created. These flammable gases, vapours, mists, and dusts form an explosive atmosphere with the oxygen in the air. If this atmosphere is ignited, explosions take place, which can result in severe harm to human life and property. To avoid the danger of explosions, protective specifications in the form of laws, regulations, and standards have been developed in most countries, which are aimed at ensuring that a high level of safety is observed. Due to the growing international economic link, extensive progress has been made in harmonizing regulations for explosion protection. The conditions for a complete harmonization were created in the European Union through the 94/9/EC and 99/92/EC Directives. There are also efforts to achieve a global harmonization with the IECEx-scheme, but much work still needs to be done in this area world-wide. The aim of this brochure is to provide both experts and interested laymen with an overview of the field of explosion protection, in conjunction with electrical apparatus and installations. It does not replace the study of the relevant statutory regulations and applicable standards.
In mining, miners underground have always lived under the threat of firedamp explosions. Herein lies the origins of explosion protection, which has been consistently developed in industrialized countries, and which now provides a high level of safety.

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2. The Basic Physic Principles and Definitions of Explosion Protection

An explosion is the sudden chemical reaction of a flammable substance with oxygen with the simultaneous release of high energy. Flammable substances may be present in the form of gases, vapours, mists or dusts. An explosion can only take place,when three factors are present simultaneously (fig. 1):

1. Flammable material (in ignitable quantities)
2. Oxygen (in the air)
3. Ignition source

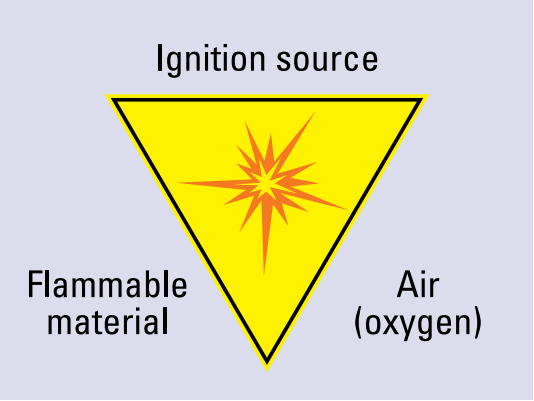


Fig. 1: **An explosion can only occur, when these three factors come together**

Certain characteristic properties of these materials are required for safety considerations. The flash point of a flammable liquid is the minimum temperature at which a liquid gives off vapour in sufficient concentration to form an ignitable mixture with air near the surface of the liquid (at normal air pressure). If the flash point of a flammable liquid is well above the maximum temperatures that arise, an explosive atmosphere can not be formed. The flash point of a mixture of various liquids may be lower than that of the individual components. In addition to the boiling point, the flash point of a liquid serves to classify liquids as highly flammable, easily flammable, and flammable liquids in the Council Directive 98/24/EC »risks related to chemical agents«.

To form an explosive atmosphere, the flammable substance must be present in a certain concentration (fig. 2).

If the concentration is too high (rich mixture) or too low (lean mixture), no explosion occurs. Instead, there is just a steady-state combustion reaction or none at all. It is only in the range between the lower and upper explosion limit that the mixture reacts explosively when ignited. The explosion limits depend on the ambient pressure and the proportion of oxygen in the air (table 2).

Table 1: **Classification of flammable liquids**

Designation of the flammable liquid	at flash point and boiling point °C
Highly flammable	Flash point < 0°C and boiling point < 35°C
Easily flammable	Flash point < 21 °C and boiling point > 35°C
Flammable	21°C < Flash point < 55°C

Depending on the speed of combustion, we speak of deflagration, explosion or detonation. An atmosphere is described as hazardous or explosive if there is danger to human life or property by an explosion. An explosive atmosphere of even just a few litres can be dangerous in an enclosed space.

Ignition source

Ignition of an explosive atmosphere can be caused by various sources:

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

Table 2: **Explosion Limits of selected Gases and Vapours**

Substance designation	Lower explosion limit [Vol. %]	Upper explosion limit [Vol. %]
Acetylene	2,3	100 (self-decomposing!)
Ethylene	2,4	32,6
Gasoline	~ 0,6	~8
Benzol	1,2	8
Heating oil/diesel	~0,6	~6,5
Methane	4,4	17
Propane	1,7	10,8
Carbon disulphide	0,6	60,0
Hydrogen	4,0	77,0

Extract from the table »Sicherheitstechnische Kenngrößen, Band 1: Brennbare Flüssigkeiten und Gase« (Safety characteristics, vol. 1: flammable liquids and gases) by E. Brandes and W. Möller as well as by T. Redeker and G. Schön – (6 th addendum)

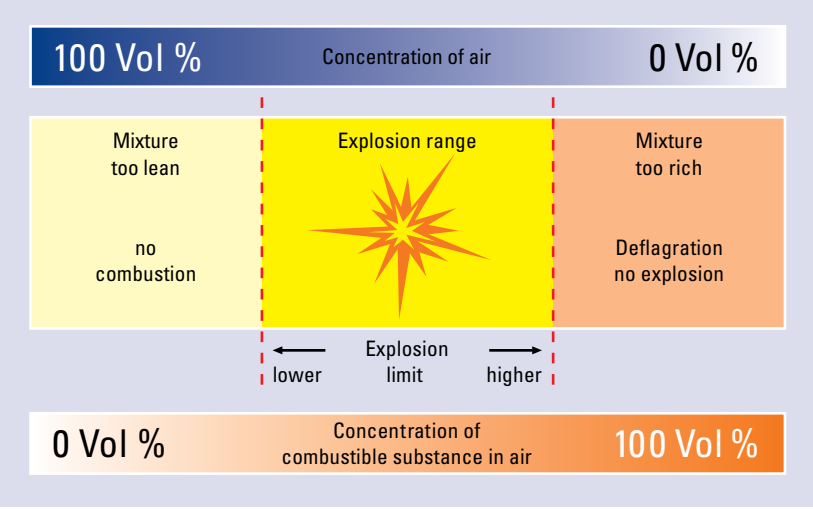


Fig. 2: **Explosion limits**

2. the basic physic principles and definitions

Preventing explosive atmospheres (Primary Explosion Protection)

The term primary explosion protection refers to all precautions, which prevent a hazardous explosive atmosphere from being created. This can be achieved by:

- avoiding flammable substances (replacement technologies)
- inerting (addition of nitrogen, carbon dioxide etc.)
- limitation of the concentration by means of natural or technical ventilation

Avoiding ignition of explosive atmospheres

If the danger of explosion cannot be completely or only partly avoided by measures of preventing the formation of an hazardous explosive atmosphere, then measures must be taken that avoid the ignition of the explosive atmosphere.

The required safety level of these measures depends on the possible danger potential in the installation location. The hazardous areas are therefore divided into zones, according to the probability of an explosive atmosphere being formed (see Section 3.2.2).

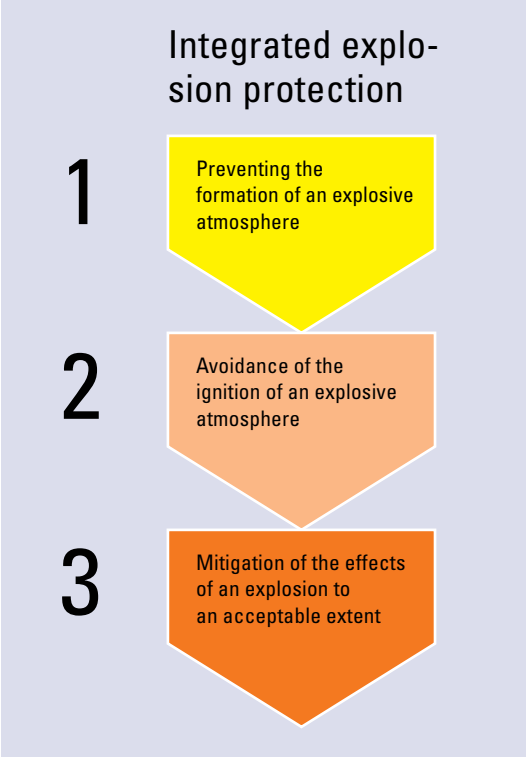
Mitigation of the explosion effects (Constructive Explosion Protection)

If hazardous explosive atmospheres cannot be safely avoided and their ignition cannot be excluded, then measures must be taken which limit the effect of explosions to a safe degree, for example, through the use of:

- flameproof or pressure surge resistant design
- explosion relief devices
- explosion suppression by means of extinguishers

The principle of integrated explosion protection requires following explosion protection measures in a certain sequence.

Fig. 3: **Basic principles of explosion protection**



3. statutory regulations and standards

3.1 World-wide

3.1.1 General

The International Electrotechnical Commission (IEC) is responsible for the global standards on the field of electrical engineering.
IEC publications dealing with the explosion protection of electrical devices and installations are developed by the Technical Committee TC31 and can be seen as recommendations which are a basis for almost all standards. Up until a few years ago, requirements for areas with potentially explosive gases have been stipulated in standard series 60079 and for areas containing combustible dusts in series 61241. As numerous requirements are similar for both areas, the two standard series will be combined in series IEC 60079. For some standards this step has already been taken, others will follow.

National regulations, however, may differ from these standards. Based on this, it is necessary to examine the extent to which the IEC-standards may be applied in the different countries.

3.1.2 Equipment

The different methods of ensuring ignition protection of devices are called types of protection. These are described in different parts of the IEC-series 60079 or 61241. These are construction regulations that are acknowledged in many countries (see table 3).

3.1.3 Erection and operation

Equipment used in hazardous areas has to be classified in zones, according to the degree of danger in regard to the probability of the occurrence of a potentially explosive atmosphere (please also see 4.1). For this purpose IEC developed two standards.

IEC 60079-10-1:
Classification of areas – explosive gas atmospheres

IEC 60079-10-2:
Classification of areas – combustible dust atmospheres

Further standards are available for erection and operation of electrical installations:

IEC 60079-14:
Design, selection and erection of electrical installations

IEC 60079-17:
Inspection and maintenance of electrical installations

IEC 60079-19:
Equipment repair, overhaul and reclamation

3. statutory regulations and standards

Table 3: **Electrical Equipment for Explosive Atmospheres**

	IEC	EN
General requirements	IEC 60079-0	EN 60079-0
Equipment protection by flameproof enclosures »d«	IEC 60079-1	EN 60079-1
Classification of areas – Explosive gas atmospheres	IEC 60079-10-1	EN 60079-10-1
Classification of areas – Combustible dust atmospheres	IEC 60079-10-2	EN 60079-10-2
Equipment protection by intrinsic safety »i«	IEC 60079-11	EN 60079-11
Equipment protection by pressurized room »p«	IEC 60079-13	EN 60079-13
Installations design, selection and erection	IEC 60079-14	EN 60079-14
Equipment protection by type of protection »n«	IEC 60079-15	EN 60079-15
Electrical installations inspection and maintenance	IEC 60079-17	EN 60079-17
Equipment protection by encapsulation »m«	IEC 60079-18	EN 60079-18
Equipment repair, overhaul and reclamation	IEC 60079-19	EN 60079-19
Equipment protection by pressurized enclosure »p«	IEC 60079-2	EN 60079-2
intrinsically safe systems	IEC 60079-25	EN 60079-25
Equipment with equipment protection level (EPL) Ga	IEC 60079-26	EN 60079-26
Fieldbus intrinsically safe concept (FISCO)	IEC 60079-27	EN 60079-27
Protection of equipment and transmission systems using optical radiation	IEC 60079-28	EN 60079-28
Gas detectors – Performance requirements of detectors for flammable gases	IEC 60079-29-1	EN 60079-29-1
Gas detectors – Selection, installation, use and maintenance of detectors for flammable gases and oxygen	IEC 60079-29-2	EN 60079-29-2
Gas detectors – Performance requirements of open path detectors for flammable gases	IEC 60079-29-4	EN 61241-1
Electrical resistance trace heating – General and testing requirements	IEC 60079-30-1	EN 60079-30-1
Electrical resistance trace heating – Application guide for design, installation and maintenance	IEC 60079-30-2	EN 60079-30-2
Equipment dust ignition protection by enclosure »t«	IEC 60079-31	EN 60079-31
Equipment protection by powder filling »q«	IEC 60079-5	EN 60079-5
Equipment protection by oil immersion »o«	IEC 60079-6	EN 60079-6
Equipment protection by increased safety »e«	IEC 60079-7	EN 60079-7
Protection by intrinsic safety »iD«	IEC 61241-11	EN 61241-11
Type of protection »pD«	IEC 61241-4	EN 61241-4
Artificial ventilation for the protection of analyser(s)	IEC/TR 60079-16	
Methods for determining the minimum ignition temperatures of dust	IEC 61241-2-1	EN 50281-2-1
Method for determining the electrical resistivity of dust in layers	IEC 61241-2-2	EN 61241-2-2
Method for determining minimum ignition energy of dust/air mixtures	IEC 61241-2-3	
Safety devices required for the safe functioning of equipment with respect to explosion risks		EN 50495

3.1.4 IECEx

Like the technical and organisational procedures and measures for the prevention of explosions, the physiochemical principles for the development of explosions are equally valid all over the world, despite minor differences.

Therefore, as a natural next step it was necessary to regulate the conditions for approval of electrical devices on a global basis and to make free global trade possible with the certificates valid in different countries and regions. So the IEC introduced a procedure whose objective is standardization: the IEC-Ex-scheme.

Throughout the world there are now 35 acknowledged IECEx certification bodies (ExCB = Certification Body) and 36 acknowledged IECEx test laboratories (ExTLs) that are accredited according to high uniform benchmarks and that are controlled regularly. IECEx follows the rule that a certificate is only issued when the type tests of the samples have been passed and existence of an effective quality management system has been verified with an audit. Currently there are still regional and national approval procedures all over the world, such as, the ATEX Directive in the European Union or national approvals in the USA (UL, FM).

After having established the IECEx scheme for testing and certification of new products, another important field of explosion protection has been covered with a suitable certification scheme: maintenance and repair of explosion-protected devices. This certification procedure was named »IECEx Certified Service Facilities Program«

Depending on the maintenance and repair work, experienced assessors establish during an audit if the required personal competences in regard to the function of the respective product and the applied types of protection are available , if a sufficient amount of correct test devices are available, if measures for identification and retraceability have been fixed and executed accordingly and if subcontractors are trained and controlled.

The basis for this evaluation is given in standards »IEC 60079-19: Equipment repair, overhaul and reclamation«, the »Operational Document OD 013: IECEx Operations Manual – Assessment and Certification of Ex Repair and Overhaul Service Facilities« and »OD 014: IECEx Operational Document: Quality System Requirements for IECEx Service Facilities involved in Repair, Overhaul and Modification of Ex Equipment«.

The third component of the IECEx scheme aims in a similar direction, dealing with the certification of the personal competences of the experts working in hazardous areas. This is also meant to give operators working world-wide the security that the employed personnel has the required qualifications and experiences to do the different, sometimes very complex work in hazardous areas correctly.

3. statutory regulations and standards

3.2 European Union

3.2.1 Directives

Already in 1976, the Council of the European Community established the prerequisite of free trade of explosion protected electrical equipment within the European Union by ratifying the »Directive on the harmonization of the laws of the member states concerning electrical equipment for use in potentially explosive atmospheres (76/117/EEC)«. This directive has since become state of the art by means of execution and adaptation directives on electrical equipment.

Complete harmonization and extension to all types of equipment, electrical and non-electrical, was completed with the new Directive 94/9/EC in 1994. In 1999 Directive 99/92/EC (ATEX 137) followed, which regulates operation in hazardous areas and defines safety measures for the concerned personnel.

3.2.2 Standards

The European Standards EN 50014 - EN 50020 on electrical equipment were issued in 1978 and replaced the national standards for this equipment which had been valid up until then Europe-wide. In addition to the standards for electrical equipment published by the CENELEC, standards for non-electrical explosion-protected equipment have since been developed by the CEN.
According to an agreement between the European Committee for Electrotechnical Standardization CENELEC and the International Electrotechnical Commission IEC, the European standards for electrical equipment have been adopted unchanged by the IEC for several years. The European Standard series EN 50014, which defines the requirements on equipment to be used in explosive gas atmospheres, has been gradually replaced by the European Standards series EN 60079.
These standards have been issued as VDE 0170 in Germany. The requirements on types of protection for areas where combustible dust may occur are specified in the standard series IEC 61241. In Europe, these standards replace the existing series EN 50281. Since many requirements are identical to the standards for explosive gas atmospheres, both standard series will be summarized in the series IEC or EN 60079 (table 3).
After publication of Directive 94/9/EC the construction regulations for non-electrical devices have also been fixed in Europe with standard series EN 13463 (see table 4). Some protection principles for electrical devices have been adopted. However, some adjustments have been made to fulfil the special demands on non-electrical devices.

Table 4: **Non-Electrical Equipment for Explosive Atmospheres**

	EN
Basic method and requirements	EN 13463-1
Protection by flow restricting enclosure »fr«	EN 13463-2
Protection by flameproof enclosure »d«	EN 13463-3
Protection by constructional safety »c«	EN 13463-5
Protection by control of ignition source »b«	EN 13463-6
Protection by liquid immersion »k«	EN 13463-8

3.2.3 Erection and operation

The Directive 99/92/EC (ATEX 137)

The 99/92/EC Directive »Minimum requirements for improving the health and safety protection of worker potentially at risk from explosive atmospheres« refers to the operation of potentially explosive installations, and is therefore intended for the employer.

According to the 99/92/EC Directive, it is the duty of the employer to verify where there is a risk of explosion, classify the hazardous areas into zones accordingly, and document all measures taken to protect the personnel in the explosion protection document:

Assessment of explosion risks

When assessing the risks of explosion, the following factors are to be taken into account:

- the likelihood that explosive atmospheres will occur and their persistence
- the likelihood that ignition sources, including electrostatic discharges, will be present and become active and effective
- the installations, substances used, processes, and their possible interactions
- the scale of the anticipated effects

Zone Classification

The employer has to classify the areas in which explosive atmospheres may be present into zones, and to ensure that the minimum organisational and technical requirements of the Directive are observed (see 4.1).

Explosion protection document

An explosion protection document has to be generated, which contains at least the following information:

- assessment of the explosion risk
- protective measures taken
- zone classification
- observance of minimum requirements:

These are divided into organisational measures (instruction of workers, etc.) and technical measures (explosion protection measures).

This directive lays down the minimum requirements that may be tightened by national regulations in the individual countries.

3.2.4 Selection of devices

The Directive 94/9/EC (ATEX 95)

The EC Directive 94/9/EC »on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres« was issued in 1994 to further standardize explosion protection in the EU and make corresponding adjustments in line with a new directive approach. It specifies the requirements for explosion protected equipment and protective systems (e.g. with specifications in regard to design, certification, manufacturing and quality assurance, marking, operating instructions and declaration of conformity) by prescribing essential health and safety requirements, which have to be observed by the manufacturer and the importer.

The directive guarantees free trade within the European Community, as agreed in Article 95 (former 100 a) of the Treaty established between the European Community member states. This is also where the term generally used amongst experts, ATEX 95 or 100 a (ATEX as the abbreviation of the French designation for explosive atmosphere »atmosphères explosibles«), comes from.

3. statutory regulations and standards

The directive had to be implemented into national law without any changes/exceptions.
It applies to all industrial potentially explosive areas including mining, and also covers dust explosion protection.

Definitions

- »Equipment« means machines, apparatus, fixed or mobile devices, control components and instrumentation thereof, and detection or prevention systems which, separately or jointly, are intended for the generation, transfer, storage, measurement, control, and conversion of energy for the processing of material and which are capable of causing an explosion through their own potential sources of ignition.
- »Protective systems« is the definition for design units, which are intended to halt incipient explosions immediately and/or to limit the effective range of explosion flames and explosion pressures. Protective systems may be integrated into equipment separately and placed on the market for use as autonomous systems.
- »Components« means any item essential to the safe functioning of equipment and protective systems but with no autonomous function.
- An »explosive atmosphere« is a mixture with air, under atmospheric condition, of flammable substances in the form of gases, vapours, mists, or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture.
- A »potentially explosive atmosphere« is an atmosphere which could become explosive due to local and operational conditions.

Scope

The directive applies to equipment and protective systems for use in potentially explosive atmospheres.

Safety devices intended for use outside potentially explosive atmospheres but required for or contributing to the safe functioning of equipment with respect to the risk of explosion are also covered by the scope of this Directive. The Directive does not include a reference to mandatory standards, whereas it specifies the essential health and safety requirements to be maintained, and which are mandatory for design and construction. Protection against other hazards (e.g. electric shock) that could be caused by this equipment, is also required.

Equipment categories

The manufacturers of equipment that includes its own potential ignition sources, and therefore could cause an explosion, have to ensure that the equipment undergoes an ignition hazard assessment procedure, and takes measures according to the essential safety requirements to exclude the risk of ignition. In the directive, Group II apparatus are divided into three categories with various levels of safety (for mines Group I has two categories). The required protective measures suit the required level of safety (see 4.2.2).

Certification

Equipment for use in hazardous areas has to undergo the conformity assessment procedure defined in the directive prior to being placed on the market. Category 1 and M1 equipment must undergo an EC type examination carried out by a Notified Body. The same applies to electrical equipment and I.C.-engines of Category 2 and M2. For non-electrical equipment of this category, as well as for those of Category 3, the manufacturer is authorized to assess and document conformity with the requirements of the directive. The certificates from a Notified Body are recognized throughout the European Community.

Marking

In addition to the usual data such as the name of the manufacturer, type, serial number, and electrical ratings, any data relating to explosion protection must be contained in the marking (see also 4.6).
The CE marking of the equipment confirms that it is designed and manufactured in compliance with all applicable EC Directives. For example, an explosion protected luminaire marked with the CE conformity mark must comply with both the ATEX 95 Directive as well as the »EMC Directive«.

Operating instructions

The manufacturers operating instructions must clearly define the intended use of the equipment by the operator.
The minimum requirements for the operating instruction are include amoungst other things, Information on safe:

- putting into service
- use
- assembly and dismantling
- maintenance (servicing and emergency repair)
- installation

If necessary, special conditions for safe use have to be specified and should include notes on possible misuse that may occur as shown by experience.

Manufacturer's EC-Declaration of Conformity

Equipment and systems can be placed on the market, only if marked with the CE mark and complete with operating instructions and the manufacturer's EC-declaration of conformity. The CE conformity marking and the written EC-declaration of conformity confirm that the product complies with all requirements and assessment procedures specified in the EC Directives.

3.3. North America

3.3.1 General

The basic principles of explosion protection are the same all over the world. However, technologies have developed in North America in the field of explosion protection for electrical equipment and installations which deviate considerably from those of the IEC (International Electrotechnical Commission). The differences from IEC technologies are among others the classification of hazardous locations, the construction of apparatus and the installation of electrical systems.

3.3.2 Erection and operation

For electrical equipment and installations that are used in potentially hazardous areas in the USA the National Electrical Code (NEC) is applicable, and in Canada the Canadian Electrical Code (CEC) applies. These codes regulate facilities for electrical installations in all areas and refer to a series of Standards from other institutions that also regulate the installation and construction of equipment.

For potentially explosive atmospheres the term »hazardous (classified) locations« is used in North America. These are defined in Articles 500 and 505 of the National Electrical Code (NEC) in the USA and in Section 18 and Annex J of the Canadian Electrical Code (CEC) in Canada. Hazardous locations are locations, where fire or explosion hazards may exist due to flammable gases, vapours or mists (Class I), combustible dusts (Class II), or ignitable fibres or flyings (Class III).

3. statutory regulations and standards

Based on the likelihood or risk that an ignitable concentration of a flammable substance will be present the hazardous locations are traditionally subdivided into Division 1 and Division 2.
In 1996 the IEC classification system was introduced as a parallel system to the existing system for Class I in the USA. This system was implemented through the new Article 505. This now gives the end user the possibility to choose the system that best suits his needs. In 2005, Article 506 introduced Zones 20, 21 and 22 for areas with combustible dust.

The IEC zone classification for Class I was also introduced in Canada (CEC, 1988 edition).
All newly built facilities in Canada need to be classified according to this principle.
The traditional North American classification system divides Class I flammable gases, vapours, mists and liquids into Gas Groups A, B, C and D, and Class II combustible dusts into Groups E, F and G. Group A is the most hazardous gas group in the traditional NEC system whereas Group IIC is the most hazardous group in the IEC system in Article 505 of the NEC. In Canada both gas grouping systems may be used with the zone classification system.

The determination of the maximum surface temperature according to Article 505 in the NEC takes place in 6 temperature classes T1 to T6 in agreement with the IEC. This also includes an additional subclassification into temperature classes within a division system. After the CEC in 1998 the existing system for temperature classification was not changed.
The installation method for the zone concept according to the NEC 505 complies with the traditional class/division systems. New to the NEC along with the use of fixed pipelines and mineral isolating cables Type MI in class 1, division 1 respectively zone 1, is also the use of approved listed Type MC cable.
A significant advantage of the CEC is the increased application possibility of cables and lines. In contrast to the USA, Canada has for some time allowed the application of special cables that are similar to the ringle wire armoured cables in the IEC areas.
Further, there are different norms and standards for the construction and testing of explosion protectes electrical facilities and equipment in North America. In the USA these are predominately the Standards of the International Society for Measurement and Control (ISA), respectively the Underwriters Labratories Inc. (UL) or Factory Mutual Research Corporation (FM). In Canada it is the Canadian Standards Association (CSA).

3.3.3 Selection of devices

Degrees of Protection provided by Enclosures

As standard IEC 60 529 defines the degrees of protection provided by enclosures, as the NEMA Publication No. 250 (National Electrical Manufacturing Association) defines the degree of protection in the USA. These enclosure types cannot be exactly equated with the IEC enclosure classification designation since NEMA takes additional environmental influences (such as cooling lubricant, cutting coolant, corrosion, icing, hail) into account. The tables 7.5 and 7.6 in the appendix illustrate the types of protection according to both standards.

Certification and Marking

Equipment which has been developed and manufactured for use in hazardous locations is tested and approved in the USA and Canada by a notified testing authority. In the USA, this is for

example, the Underwriters Laboratories or Factory Mutual, and in Canada the Canadian Standards Association.

In addition to data such as manufacturer, type, serial number, and electrical data, any data relating to explosion protection must be shown on the marking of the equipment. The requirements for this are specified in the NEC, the CEC as well as, the relevant apparatus regulations of the testing authority (see 4.6).

Table 6a: **Classification of Hazardous Locations in North America**

Gases, vapors or mists Classification Class I	Dusts Classification Class II	Fibers and Flyings Classification Class III
NEC 500 CEC J18	NEC 500 CEC 18	NEC 500 CEC 18
Division 1 A location, in which ignitable concentrations of flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors - can exist under normal operating conditions, or - may exist frequently because of repair or maintenance operations or because of leakage failure of electrical equipment - might be released during breakdown or faulty operation of equipment or processes.	Division 1 A location, in which combustible dust is in the air in quantities sufficient to produce explosive or ignitible mixtures, - under normal operating conditions - due to mechanical failure or abnormal operation of machinery or equipment and might also provide a source of ignition through simultaneous failure of electric equipment, through operation of protection devices, or from other causes, or - a location in which Group E combustible dusts may be present in quantities sufficient to be hazardous.	Division 1 A location in which easily ignitible fibers/flyings are handled, manufactured, or used.
Division 2 A location in which volatile flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems or in case of abnormal operation of equipment.	Division 2 A location in which combustible dust due to abnormal operations may be present in the air in quantities sufficient to produce explosive or ignitible mixtures.	Division 2 A location in which easily ignitible fibers/flyings are stored or handled other than in the process of manufacture.

3. statutory regulations and standards

3.4 Russia

3.4.1 General

Prerequisite for the use of explosion-protected electrical equipment in Russian plants is the availability of an approval by an acknowledged test and certification centre of the Russian Federation that confirms the compliance with the requirements stated in the Russian standards.

Since 01/01/2001 a new series of standards which regulates the requirements on the design of explosion-protected electrical equipment, the classification of hazardous areas and the application of explosion-protected equipment in different protection levels in hazardous areas is effective in Russia.

One of the main tasks when establishing these standards has been the harmonization with the international standards series IEC 60079. However, most Russian standards show national deviations compared to the international standards.

3.4.2 Erection and operation

Hazardous areas

All hazardous areas where potentially explosive mixtures consisting of gases or vapours and air or combustible dusts or where fibres in the air may occur, are evaluated from two points of view with regards to hazard:

- Probability of the occurrence of a potentially explosive atmosphere in the respective area.
- Safety-relevant key figures of the substances, gases, vapours dusts that are used and of the ignition sources that may be found.

For evaluation of the possible use of explosion protected equipment in an installation, the safety-relevant parameters of the explosion protection of the devices and the parameters of a potentially explosive atmosphere in this area of the installation

Table 6c: **Temperature classes**

Ignition temperature of gas or vapour in °C	Temperature class	Max. surface temperature on the equipment °C
> 450	T1	450
> 300 up to 450	T2	300
> 280 up to 300	T2A	280
> 260 up to 280	T2B	260
> 230 up to 260	T2C	230
> 215 up to 230	T2D	215
> 200 up to 300	T3	200
> 180 up to 200	T3A	180
> 165 up to 180	T3B	165
> 160 bis 165	T3C	160
> 135 bis 200	T4	135
> 120 bis 135	T4A	120
> 100 bis 135	T5	100
> 85 bis 100	T6	85

Table 6b: **Groups**

Gas	Dust
A (Acethylene)	E (metal)
B (Hydrogen)	F (carbon)
C (Ethylene)	G (flour plastic)
D (Propane)	

have to be in tune. In this context it is necessary to classify the hazardous area in zones according to the probability of the occurrence of hazardous potentially explosive atmosphere.
Currently there are two possibilities of classification in effect in Russia: the new classification according to GOST R 51330-99 and the old classification according to the long standing erection regulations for electrical installations. The reason behind this is the long-time use of classification of Ex-zones pursuant to the hitherto valid standard. So this classification does not only apply to many currently existing installations but also to those installations that are reconstructed.

3.4.3 Selection of devices

Explosion protection level

Electrical devices are classified according to their explosion protection level. The term »explosion protection level« basically corresponds to the determination in regard to equipment category given in the European Directive 94/9/EC, respectively the equipment protection level pursuant to IEC 60079-9, but with a different numbering, a different classification into types of protection, and a different grading of the underground areas. Direct assignment of protection level 0, 1, 2 to Zone 0, 1, 2 does not exist. Erection regulations GOST R 51330.13-99 stipulates what type of protection may be used in which zone and this corresponds to the definition given in IEC 60079-14.

Protection level 2

Electrical equipment with a normal degree of explosion protection (for marking of explosion protection figure 2 for equipment of Group II and the Cyrillic letters PB for Group I are added). This is explosion-protected electrical equipment with which explosion protection is guaranteed under normal operating conditions. This explosion protection level can be ensured with the following types of protection: ia, ib, ic, px, pz, q, e, m, d, o, s.

Protection level 1

Explosion-protected electrical equipment with a high degree of explosion protection (for marking of explosion protection figure 1 for electrical equipment for Group II and the Cyrillic letters РП for Group I are added). This is explosion-protected electrical equipment with which explosion protection is ensured in normal operating conditions and when device errors or error conditions occur that may normally be expected. This explosion protection level can be guaranteed with the following types of protection: ia, ib, px, d, s.

Protection level 0

Special explosion-protected electrical equipment with a very high degree of explosion protection (for marking of explosion protection the figure 0 for electrical equipment of Group II and the Cyrillic letters PO for Group I are stated). It is explosion-protected electrical equipment for which additional protection measures have been taken within a standardized type of protection. This explosion protection level can be ensured with the following types of protection: ia, s.

Marking

The marking specifications are given in standard GOST R 51330.0-99 and in the standards for the different types of protection (see 4.6).

4. technical principles

4.1. Zone classification

Hazardous areas are classified into zones to facilitate the selection of appropriate electrical apparatus as well as the design of suitable electrical installations. Zone classification is a reflection of the probability of a potentially explosive atmosphere occuring again. Information and specifications for zone classification of potentially explosive gas areas can be found in IEC 60079-10-1, and for areas with potentially combustable dust in IEC 60079-10-2.
When classifying hazardous areas into zones and determining the required protection measures, the highest possible hazard potential has to be taken into account. If there is no qualified person available in the company for evaluation of explosion hazard and determination of the required measures, a qualified body should be employed. The devices used in the defined danger area have to fulfil the requirements of the respective equipment category or equipment protection level.

A survey on zone classification and the assessment of devices according to their category is shown in table 8.

Table 7: **Zone Classification**

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

Table 8: **Zones and allocation of equipment according to the category and the quipment protection level**

	Zone	Duration of the occurrence of an explosive atmosphere	Equipment category	Equipment protection level EPL
Gases, vapours, mists	0	continuously, for a long period frequently	1G	Ga
	1	occasionally	2G	Gb
	2	rarely and for a short period	3G	Gc
Dusts	20	continuously, for a long period, frequently	1D	Da
	21	occasionally	2D	Db
	22	rarely and for a short period	3D	Dc

4.2 Categories and Equipment Protection Level EPL

4.2.1 General

Depending on the probability of the occurrence of a potentially explosive atmosphere, different safety requirements are posed on the equipment that is used. Safety level of the devices is adjusted to the hazard potential in the different zones.

With EC-Directive 94/9/EC (ATEX 95) explosion-protected devices are classified in categories in Europe. On an international level, equipment protection level EPL has been introduced with IEC 60079-0 of 2007.

Equipment has to be designed in such a way that explosion protection measures on different protection levels (degree of protection) are included, depending on the category or EPL.

4.2.2 Categories

For devices for use in potentially explosive areas – excluding firedamp mines – three categories are provided:

Category 1:
Very high degree of safety. Safe even when infrequent device errors occur. Two independent explosion protection measures, or safe even, when two failures occur independently.

Category 2:
High degree of safety. Safe even when there are frequent device errors that may usually be expected. Even safe when a failure occurs.

Category 3:
Normal degree of safety. Safe during normal operation. Additional letter »G« or »D« refers to the use of the device in areas with potentially explosive gases (G) or in areas with combustible dust (D).

Devices for use in firedamp mines are classified in two categories:

Category M1:
Very high degree of safety. Safe even when infrequent device errors occur. Devices may still be operated when a potentially explosive atmosphere occurs.

Category M2:
High degree of safety. Safe during normal operation, even under difficult operating conditions. Devices must be turned off in case of potentially explosive atmosphere.

4.2.3 Equipment protection level EPL

Pursuant to IEC 60079-0 (2007), devices for potentially explosive areas are classified into three protection levels (for devices used in firedamp mines two protection levels are determined):

EPL Ga or Da:
Devices with a »very high« protection level for use in hazardous areas where there is no ignition hazard during normal operation and in case of foreseeable or infrequent faults/malfunctions.

EPL Gb or Db:
Devices with a »high« protection level for use in hazardous areas where there is no ignition hazard during normal operation or in case of foreseeable faults/malfunctions.

EPL Gc or Dc:
Devices with »extended« protection level for use in hazardous areas where there is no ignition hazard during normal operation and where some additional protective measures are applied to ensure that the usually foreseeable malfunctions of the devices do not cause ignition hazard.

The letters »G« and »D« determine whether the device is suitable for use in areas with potentially explosive gases (G) or for areas with combustible dust (D).

Devices for firedamp mines:

EPL Ma:
Device with a »very high« protection level for mounting in firedamp mines, which ensures the required degree of safety so that no ignition hazard occurs during normal operation, or in case of foreseeable or infrequent faults/malfunctions, even if the device is still in operation during a gas leak.

EPL Mb:
Device with a »high« protection level for mounting in firedamp mines, which ensures the required degree of safety so that there will be no ignition hazard during normal operation or in case of foreseeable faults/malfunctions, during the period between gas leak and turning-off of the device.

Range of application of equipment of a certain category or EPL in the respective danger zones in potentially explosive areas is shown in table 7.

4.3 Groups

4.3.1 General

Equipment Groups according to European Directive 94/9/EC (ATEX 95)

The ATEX-Directive classifies the equipment for use in potentially explosive Atmospheres in two groups:

Equipment group I:
Equipment intended for use in underground parts of mines, and in those parts of surface installations of such mines, liable to be endangered by firedamp and/or combustible dust.

Equipment group II:
Equipment intended for use in other places liable to be endangered by explosive atmospheres.

Up until now explosion-protected equipment has been divided in two groups:

Groups according to IEC 60079-0

Group I:
Equipment for use in mines susceptible to firedamp.

Group II:
Equipment for use in places with an explosive gas atmosphere other than mines susceptible to firedamp..

Electrical devices for mines, where, in addition to firedamp, proportions of gases other than methane may occur, have to fulfil the requirements for group II as well as those for group I.

Devices of group II are further divided, depending on their intended field of application, into devices for areas that are hazardous because of gases, vapours or mists and those for areas that are hazardous because of dust.

With the publication of IEC 60079-0 in 2007 group III for potentially explosive areas due to dust was introduced. Group II is reserved for equipment for use in areas with explosive gases.

Group II:
Devices for areas with explosive gases, excluding mines.
Group III:
Devices for areas with combustible dusts, excluding mines.

Electrical devices of group II (gas) are divided in group IIA, IIB and IIC, depending on the properties of the potentially explosive area they are intended for (see table on page 9). This classification concerns types of protection Flameproof Enclosure and Intrinsic Safety. For type of protection Flameproof Enclosure it is based on the maximum experimental safe gap (MESG) which is a measure for the discharge behaviour of a hot flame through a narrow gap, and for Intrinsic Safety it is based on the minimum ignition current (MIC), which is a measure for the minimum ignition energy of the gases and vapours that occur.

Table 9: **Subdivision of group II**

Explosion group	typical gas	maximum experimental safe gap	Minimum ignition current ratio*
IIA	Propan	> 0,9	> 0,8
IIB	Ethylen	0,5 … 09	0,45 ... 0,8
IIC	Wasserstoff	< 0,5	< 0,45

* rel. to methane = 1

Devices for areas with combustible dust (group III) are subdivided in groups IIIA, IIIB and IIIC, depending on the type of dust:
IIIA: combustible flyings
IIIB: non-conductive dust
IIIC: conductive dust

4.3.2 Classification

The substances and thus the explosive areas in which those substances occur are classified in groups according to these criteria. The devices that are used have to be designed to fulfil the requirements of the group, which increase from IIA to IIC and from IIIA to IIIC. A device that fulfils the criteria for IIC can be used in areas that are classified as IIC, IIB and IIA, devices that fulfil the criteria for IIB can be used in areas IIB and IIA, while devices for IIA may only be used in area IIA. Devices for groups IIIA, IIIB and IIIC can be handled likewise.

4.4 Ignition temperature and temperature classes

4.4.1 General

Ignition temperature of a combustible gas, vapour or dust is the lowest temperature of a heated surface, which may ignite the gas/air or vapour/air mixture. It is virtually the lowest temperature at which a hot surface may ignite the respective explosive atmosphere.

4.4.2 Explosive gases

Combustible gases and vapours are classified in temperature classes according to their ease of ignition (see table 10). Maximum surface temperature of an electrical device always has to be lower than the ignition temperature of the gas or vapour/air mixture in which it is used. Of course, equipment that complies with a higher temperature class (e.g. T5) is also permissible for applications for which a lower temperature class is required (e.g. T2 or T3). In North America a system with further division in sub-temperature classes exists.

Table 10: **Temperature Classes**

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

4.4.3 Combustible dusts

Combustible dusts are not classified in temperature classes. Minimum ignition temperature of a dust cloud has to be compared to the maximum surface temperature of the equipment. A safety factor has to be allowed for. The maximum surface temperature of the equipment must not exceed 2/3 of the minimum ignition temperature of the dust cloud. As dusts may also deposit on the equipment, the minimum ignition temperature of the dust deposit also has to be considered (smouldering temperature). The smouldering temperature is the lowest temperature of a hot surface at which a 5 mm dust layer may ignite. Comparison to the maximum surface temperature of the equipment has to be done with a safety factor of 75 K. Thermal insulation increases with higher layers.

The dust layer may ignite with lower temperatures. That is why a reduced surface temperature on the equipment is permissible.

It is determined according to the diagram shown in picture 4 (EN 60079-14). If the layer is more than 50 mm thick the smouldering temperature has to be determined through a laboratory test. This also applies to a layer thickness of more than 5 mm when the smouldering temperature at a layer thickness of 5 mm is lower than 250 °C. Laboratory tests are also required when the equipment is completely covered with combustible dust.

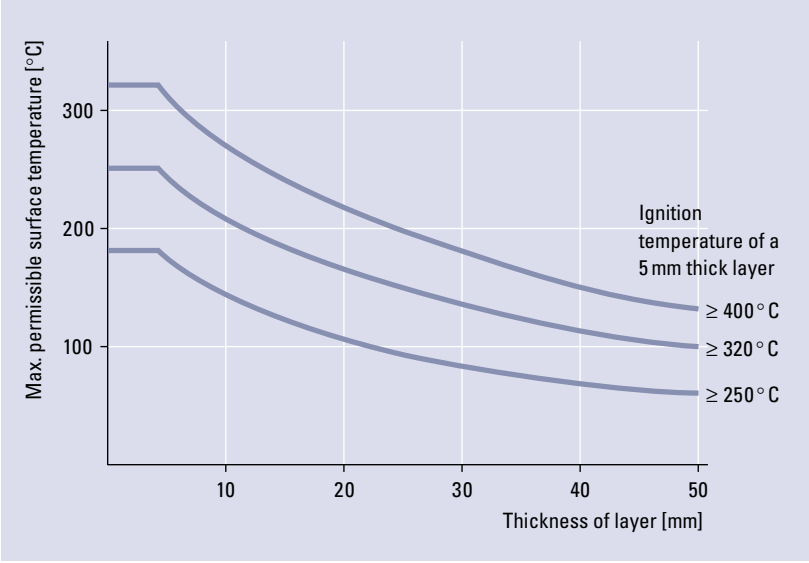


Fig. 4: **Determination of the max. Surface Temperature of Dust Layers of 5 mm to 50 mm**

4.5 Types of protection

In areas in which an explosive atmosphere may still be expected despite the implementation of preventative measures, only explosion-protected equipment may be used. Electrical explosion-protected equipment for use in areas with explosive gases can be designed in different types of protection, pursuant to the construction regulations of standard series IEC 60079. If electrical equipment is meant to be used in areas with combustible dust, standard series IEC 61241 has to be applied.

Types of protection for non-electrical equipment are stipulated in standard series EN 13463. The type of protection a manufacturer employs for a certain device mainly depends on the type and

function of the device. For some types of protection there are several protection levels. These correspond to the equipment categories pursuant to Directive 94/94/EC, or to the equipment protection levels EPL according to IEC 60079-10 published in 2007. Therefore, there is design Ex ia for Intrinsic Safety, which is classified as being category 1 or EPL Ga. It can be installed in Zone 0. Design Ex ib corresponds to category 2 or EPL Gb which is suitable for Zone 1. With regards to safety all standardized types of protection within a category or an equipment protection level can be considered as being equal.

Tables 11 – 15 show an overview of the standardized types of protection and describe the basic principle and the customary fields of application.

Table 11: **Types of Protection for Electrical Apparatus in Explosive Gas Atmosphere, Part 1**

Type of protection in accordance in IEC, EN, ISA and NFPA	Presentation (diagram)	Basic principle	Main application
Increased safety »e« EN 60079-7 ISA 60079-7 IEC 60079-7		Here additional measures are applied to increase the level of safety, thus preventing the possibility of inadmissibly high temperatures and the occurrence of sparks or electric arcs within the enclosure or on exposed parts of electrical equipment, where such ignition sources would not occur in normal service.	Terminal and connection boxes, control boxes for installing Ex-components (which have a different type of protection), squirrel cage motors, light fittings
Flameproof enclosure »d« EN 60079-1 ISA 60079-1 IEC 60079-1		Parts which can ignite a potentially explosive atmosphere are surrounded by an enclosure which withstands the pressure of an explosive mixture exploding inside the enclosure and prevents the transmission of the explosion to the atmosphere surrounding the enclosure.	Switchgear and control gear, display units, control systems, motors, transformers, heating equipment, light fittings
Pressurized enclosure »p« EN 60079-2 NFPA 496 IEC 60079-2		The formation of a potentially explosive atmosphere inside an enclosure is prevented by maintaining a positive internal pressure of protective gas in relation to the surrounding atmosphere and, where necessary, by supplying the inside of the enclosure with a constant flow of protective gas which dilutes any com¬bustible mixtures.	Switching and control cabinets, analysers, large motors px = use in Zone 1, 2 py = use in Zone 1, 2 pz = use in Zone 2
Intrinsic Safety »i« EN 60079-11 ISA 60079-11 IEC 60079-11		Equipment that is used in a potentially explosive area only con¬tains intrinsically safe electric circuits. An electric circuit is intrinsically safe if any spark or thermal effect produced under specified test conditions (which include normal operation and specifiied fault conditions) is not capable of causing ignition of a given explosive atmosphere.	Measurement and control technology, field bus technology, sensors, actuators ia = use in Zone 0, 1, 2 ib = use in Zone 1, 2 ic = use in Zone 2 [Ex ib] = associated electrical apparatus — installation in the safe area
EN 60079-25 IEC 60079-25		Intrinsic Safety evaluation for defined systems (equipment and cables)	Intrinsically safe systems
EN 60079-27 ISA 60079-27 IEC 60079-27	FISCO Ex ia IIC T4	Definition of the physical and electrical limit values of the intrinsically safe bus string	Intrinsically safe field bus systems (FISCO) for Zone 1

Table 12: **Types of Protection for Electrical Apparatus in Explosive Gas Atmosphere, Part 2**

Type of protection in accordance IEC, EN and ISA	Presentation (diagram)	Basic principle	Main application
Ölkapselung »o« EN 60079-6 ISA 60079-6 IEC 60079-6		Electrical equipment or parts of electrical equipment are immersed in a protective fluid (e.g. oil) in such a way that a potentially explosive atmosphere existing above the surface or outside of the encapsulation cannot be ignited.	Transformers, starting resistors
Powder filling »q« EN 60079-5 ISA 60079-5 IEC 60079-5		Filling the enclosure of electrical equipment with a fine grained packing material has the effect of making it impossible for an electric arc created in the enclosure under normal operating conditions to ignite a potentially explosive atmosphere surrounding the enclosure. Ignition must neither be caused by flames nor by elevated temperatures on the enclosure surface.	Sensors, electronic ballasts, transmitters
Encapsulation »m« EN 60079-18 ISA 60079-18 IEC 60079-18		Parts that are capable of igniting an explosive atmo¬sphere are enclosed in a compound in such a way that ignition of an explosive atmosphere is prevented.	ma = use in Zone 0, 1, 2 mb = use in Zone 1, 2
Type of protection »n_« EN 60079-15 ISA 60079-15 IEC 60079-15		Electrical equipment cannot ignite an explosive atmosphere surrounding it (during normal operation and under defined abnormal operating conditions).	All electrical equipment for Zone 2 nA = non-sparking apparatus nC = fittings and components nR = restricted breathing nL = limited energy
Optical radiation »op_« EN 60079-28 IEC 60079-28		Appropriate measures prevent ignition of an explosive atmosphere by optical radiation.	Optical fibre There are three different methods: Ex op is = inherently safe optical radiation Ex op pr = protected optical radiation Ex op sh= optical system with interlock

Table 13: **Electrical Apparatus for Use in the Presence of Combustible Dust**

Type of protection in accordance in IEC, EN and ISA	Presentation (Diagram)	Basic principle	Main application
Protection by enclosure »t« IEC 60079-31 EN 60079-31 *IEC 61241-1* *EN 61241-1* *ISA 61241-1*		Tightness of the enclosure prevents ingress of dust or limits it to a nonhazardous amount. So ignitable equipment can be fitted into the enclosure. The surface temperature of the enclosure must not ignite the surrounding atmosphere.	Switchgear and control gear, connection and terminal boxes, motors, light fittings
Pressurized enclosure »p« IEC 61241-4 EN 61241-4 ISA 61241-2		The formation of a potentially explosive atmosphere inside an enclosure is prevented by maintaining a positive internal pressure of protective gas in relation to the surrounding atmosphere and, where necessary, by sup¬plying the inside of the enclosure with a constant flow of protective gas which dilutes any combustible mixtures.	Switching and control cabinets, motors
Intrinsic Safety »i« IEC 60079-11 EN 60079-11 *IEC 61241-11* *EN 61241-11* *ISA 61241-11*		Equipment that is used in a potentially explosive area only contains intrinsically safe electric circuits. An electric circuit is intrinsically safe if any spark or thermal effect produced under specified test conditions (which include normal operation and specified fault conditions) is not capable of causing ignition of a given explosive atmo¬sphere.	Measurement and control technology, fieldbus technology, sensors, actuators [Ex ibD] = associated electrical apparatus — installation in the safe area
Encapsulation »m« EN 60079-18 IEC 60079-18 *IEC 61241-18* *EN 61241-18* *ISA 61241-18*		Parts that are capable of igniting an explosive atmo¬sphere are enclosed in a compound in such a way that ignition of an explosive atmosphere is prevented.	Display units, sensors

Type of ignition protection for areas with combustible dust are integrated into the series of standards 60079. The symbols for these types of ignition protection are simplified in standard IEC 60079-0 (Table 14).

Tabelle 14: **Kennzeichnung nach Normenreihen IEC 61241 und IEC 60079**

Normenreihe 61241		**Normenreihe 60079**		**Einsatzbereich**
Norm	Symbol	Norm	Symbol	Zone
Schutz durch Gehäuse				
IEC 61241-1	tDA20, tDB20 tDA21, tDB21 tDA22, tDB22	IEC 60079-31	ta	20
			tb	21
			tc	22
Überdruckkapselung				
IEC 61241-4	pD21 pD22	IEC 60079-2	pb	21
			pc	22

Intrinsic safety				
IEC 61241-11	iaD20 iBD21	IEC60079-11	ia	20
			ib	21
Encapsulation				
IEC 61241-18	maD20 maD21	IEC 60079-18	ma	20
			mb	21
			mc	22

Table 15: **Types of Protection for Non-electrical Apparatus used in Explosive Gas Atmosphere and in the Presence of Combustible Dust**

Type of protection in accordance in IEC or EN	Presentation (Diagram)	Basic principle	Main application
Constructional safety »c« EN 13463-5		Proven technical principles are applied to equipment types which do not have any ignition source under normal operating conditions, so that the risk of mechanical failures which may cause ignitable temperatures and sparks is reduced to a minimum	Couplings, pumps, gear drives, chain drives, belt conveyors
Flameproof enclosure »d« EN 13463-3		Parts which can ignite a potentially explosive atmo-sphere are surrounded by an enclosure that with-stands the pressure of an explosive mixture exploding inside the enclosure and prevents the transmission of the explosion to the atmosphere surrounding the enclosure.	Brakes, couplings
Pressurized enclosure »p« EN 600079-2		The formation of a potentially explosive atmosphere inside an enclosure is prevented by maintaining a positive internal pressure of protective gas in relation to the surrounding atmosphere and, where necessary, by supplying the inside of the enclosure with a constant flow of protective gas which dilutes any combustible mixtures.	Pumps
Control of ignition source »b« EN 13463-6		Sensors are integrated in the equipment to detect emerging hazardous conditions and to take countermeasures at an early stage, before potential ignition sources become effective. The applied measures can be initiated automatically by means of a direct connection between the sensors and the ignition protection system or manually by issuing a warning message to the operator of the equipment.	Pumps, belt conveyors
Liquid immersion »k« EN 13463-8		Ignition sources are rendered inactive by immersion in a protective liquid or by constant moistening using a liquid film.	Submersible pumps, gears, liquid immersion
Flow restricting enclosure »fr« EN 13463-2		The effective sealing of an enclosure can reduce ingress of explosive atmosphere to such an extent that no potentially explosive atmosphere can form inside. Pressure differences between the internal and the external atmo¬sphere because of change in temperature have to be taken into account. Application is limited to equipment category 3.	Equipment exclusively for Zone 2 or Zone 22

4.5.1 Applications of Type of Protection »Intrinsic Safety«

The type of protection »Intrinsic Safety« is based on the principle of energy limitation within an electric circuit. The energy from a power circuit capable of causing an explosive atmosphere to ignite is thus limited to such an extent that the surrounding explosive atmosphere cannot ignite as a result of sparks or inadmissible surface heating of the electrical components.

The type of protection »Intrinsic Safety« is particularly used in measurement and control technology, as no high currents, voltage and power are required here.

Terms and Definitions

Intrinsically safe electrical circuit
An electric circuit in which neither a spark nor the effect of heat can cause a defined explosive atmosphere to ignite.

Intrinsically safe apparatus
Electrical apparatus in which all circuits are intrinsically safe.

Associated apparatus
Electrical apparatus which contains circuits, some of which are intrinsically safe and some are not, and which is constructed such that the non-intrinsically safe circuits cannot adversely affect the intrinsically safe circuits (table 16).
An essential aspect of the type of protection »Intrinsic Safety« is reliability with regard to the observance of voltage and current limit values, even if determined faults may occur. Intrinsically safe apparatus and intrinsically safe components from related equipment are classified in different levels of protection »ia«, »ib« or »ic« with regard to infallibility. The various protection levels are attuned to the different zones. Intrinsic safety »ia« is suitable for use in Zone 0, protection level »i« for use in Zone 1 and protection level »ic« is suitable for use in Zone 2.

Table 16: **Difference between intrinsically safe and associated apparatus**

Intrinsically safe apparatus	Associated apparatus	
These contain intrinsically safe circuits only.	These contain both intrinsically safe and non-intrinsically safe electric circuits.	
Ex ib IIC T6	[Ex] ib IIC T6	Ex de [ib] IIC T6
All necessary information such as category, explosion group and temperature class is provided.	The square brackets indicate that the associated electrical apparatus contains an intrinsically safe electric, circuit that may be introduced into Zone 1, gas groups IIA, IIB and IIC.	
The apparatus may be used in Zone 1	The apparatus has to be installed outside of the potentially explosive area.	Thanks to being integrated in a flameproof enclosure »d«, the apparatus may be used in Zone 1.

Isolation of Intrinsically Safe Circuits from

An important measure for intrinsically safe circuits is the safe isolation of all intrinsically safe circuits from non intrinsically safe circuits (fig. 6). Safe electrical isolation is always required, with the exception of safety barriers.

Electric isolation is generally recommended for Zone 0. Zener diodes, used for limiting voltage, as well as other semiconductor components are considered to be fallible and must therefore be safeguarded by means of redundant components. Wire wound or sheet resistors for current limitation are considered to be infallible components (they have high resistivity in the event of a fault). Therefore one single component is sufficient.

Fig. 6: **Electric Isolators IS pac**

Single fault safety

If one safety-relevant component fails, a second component has to perform the task (protection level »ib«: a redundant component).

Double fault safety

If safety-relevant components fail, a third component has to perform their task (level of protection »ia«: two redundant zener diodes).

Zone 2 and Division 2

Intrinsic safety »ic« - energy-limited circuits »nL« - non incendive »NI«

In the USA the principle of energy limitation is treated differently, depending on the field of application. The demands on devices for Class I Zone 2 correspond to a large extent to the IEC-requirements. Intrinsic safety type ic will replace the energy-limited circuits type nL, as stipulated in the IEC-standards. For Class I Division 2, energy limitation will be implemented as >non-incendive< (NI) circuits. The difference of the various methods is shown in tables 17 and 18.

Table 17: **Standards**

	Ex ic	Ex nL	NI
Description	Intrinsic safety	Energy limited	„Non incendive“
Classification area (gas)	Zone 2	Zone 2	Class I Div. 2
Classification area (dust)	Zone 22 (Ex icD)	Zone 22 (Ex nL)	Class II + III Div. 2
Standard	IEC 60079-11	IEC 60079-15	NEC500
Fieldbus	IEC 60079-27-FISCO	IEC 60079-27-FNICO	--
Maintenance	IEC 60079-17	IEC 60079-17	ANSI/ISA 12.12.01

Note: Ex nL will be replaced by Ex ic.

Table 18: **Installation and maintencance**

	Ex ic	Ex nL	NI
Cabel	IEC 60079-14		US-standard
Marking	Yes. If colored, blue	No requirements	No requirements
Isolation to non-Ex i/nL Circuits	50 mm	No (50 mm to I.S.)	Separation
Clearance to blank conducting material	to non-Ex i: 50 mm; to separate Ex i: 6mm; to earth: 3mm	No special requirements	Separation
Verification of intrinsic safe circuits	Yes	Yes	Yes
Operational maintenance *)	Yes	Yes	Yes
Corrective maintenance *)	Yes	Yes	No

*) NEC 500 differentiates between servicing and repair. For example, during repair the replacement of defective non-incendice components is not allowed.

4.5.2 Applications of Type of Protection »c«

Non-electrical apparatus are often realised with the type of protection “Constructional safety”. The risk of failure, which may cause ignition sources in an apparatus, is reduced to a low level by means of constructional measures for this type of protection. To do so, for example, for hot surfaces, mechanically generated sparks, and electrostatic discharges are examined. The measures depend mainly on the equipment type and may vary significantly. Here, the examined material combination, dimensioning, tolerances, and lubricants of moving parts play a role. Even servicing intervals and monitoring of the service life may be of vital importance.
The manufacturer defines the intended use in the operating instructions. By doing so, ambient and

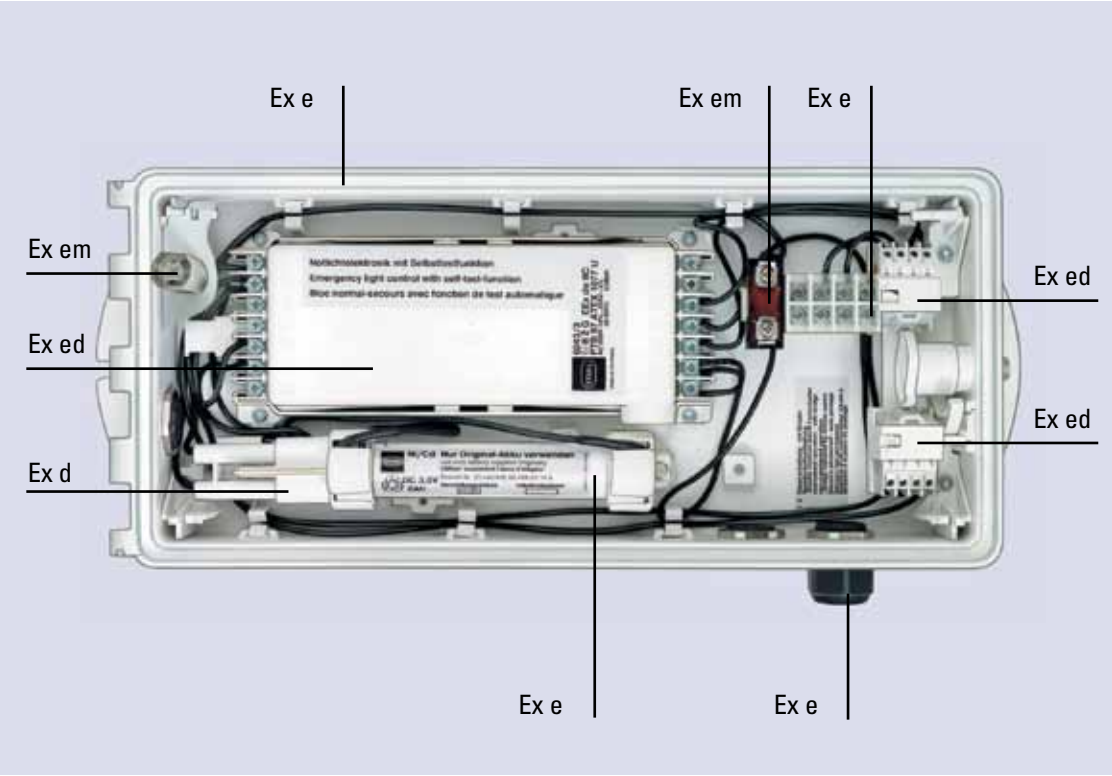


Fig. 5: **Combination of Types of Protection Emergency Light Fitting C-Lux 6108**

operating conditions, as well as the admitted operating parameters are specified. The operator has to observe the operating instructions.

4.5.3 Application and Combination of Types of Protection »d« and »e«

The most important type of protection for switchgear is »Flameproof Enclosures«, usually in conjunction with »Increased Safety«. Switchgear does produce sources of ignition in normal use and therefore »Increased Safety« alone is not applicable as type of protection for switchgear, since »Increased Safety« is based on the principle of avoiding sources of ignition through additional measures.
However, »Increased Safety«, in conjunction with »Flameproof Enclosures«, cut a fine figure for switchgear and control gear. Modern, explosion protected luminaires also use a combination of several types of protection to achieve the best results with regard to safety, function, and econmy (fig. 5).

4.6 Marking

IEC

Marking of electric devices is defined in IEC 60079-0 issued in 2004 for explosive gas atmospheres and in IEC 61241-0 issued in 2004 for areas with combustible dusts. In addition to the manufacturer's name or trade mark, type designation, serial number, and the test centre with certificate number, a special coding is required that describes the intended use of the device:

- Ex-symbol
- Symbol of every type of protection that has been applied
  The associated electrical devices that are meant to be installed in the hazardous areas, have to be marked with the symbols for the type of protection in squared brackets, e.g. Ex d[ia] IIC T4.
- Group II, IIA, IIB or IIC for potentially explosive gas atmospheres
- Temperature class for areas with potentially explosive gas atmospheres or max. surface temperature in °C for areas in which combustible dusts may be present.
  Examples:
  Ex d e IIC T4
  Ex d [ia] IIB T5
  Ex mbD T120°C

The types of protection have to clearly show which level they achieve. Some types of protection already contain the appropriate symbol (e.g. ia):
With others the letter a, b or c has to be added
d -> db
Example:
Ex db eb IIC T4
Ex db [ia] IIB T5
The second variant (called alternate marking in the standard) is preferentially used.

With this standard, groups for areas where potentially explosive dusts may be present have been introduced as well:

IIIA: combustible flyings
IIIB: non-conductive dust
IIIC: conductive dust
Example for marking of dust:
Ex tb IIIB T120°C

Europe

In Europe, in addition to the marking according to the standard the requirements pursuant to EC-Directive 94/9/EC (ATEX 95) have to be met as well:

- Manufacturer's address
- Symbol CE and the identification number of the notified body
- and category 1, 2 or 3, as well as group II and the letter G (gases) or D (dust)
  Example: Ex 2 II G

Previously, »Ex« was replaced by »EEx« in Europe, if the marking was done pursuant to the standard. Reference has thus been made to the European Standards (EN 50014 ff), which differed from the IEC-standards at that time. With the current editions of the standards this is no longer required, thus devices in Euope are only marked »Ex« now as well.

Up until now standards for non-electrical devices have only been developed by CEN in Europe. Such standards do not yet exist on an international level. Marking closely follows the marking of electrical devices.
Exceptions:

- Ex is not stated, as with ATEX the Ex -sign already refers to explosion protection

> Ignition protection level is not given. Alternative marking is not used either. The equipment protection level has to be defined with the category.

A summary of the topic marking of electrical and non-electrical devices can be found in the enclosure 7.7 and 7.8.

North America

In addition to such data as for example, manufacturer, type, serial number and electrical data, data concerning explosion protection must be included in the marking of the equipment. Specifications are given in NEC, CEC and the respective construction regulations of the test centres.

Class I, II & III, Division 1 and 2

Approved electrical equipment for Class I, Class II and Class III, Division 1 and Division 2 has to be marked with the following data:

1. Class(es), Division(s)
   (optional, except for Division 2)
2. Gas-/dust-group(s)
3. Operating temperature or temperature class
   (optional for T5 and T6)
   Example: Class I Division 1 Groups C D T4

Class I, Zone 0, 1 and 2

For equipment for use in Class I, Zone 0, Zone 1 or Zone 2 a difference is made between »Division Equipment« and »Zone Equipment«.

(1) Division Equipment
Equipment approved for Class I, Division 1 and/or Class I, Division 2 may be marked with the following data:

1. Class I, Zone 1 or Class I, Zone 2
2. Gas group(s) IIA, IIB or IIC
3. Temperature class
4. Types of protection
   Example: Class I Zone 1 d,e IIC T4

(2) Zone Equipment
Equipment complying with several types of protection pursuant to Article 505 of NEC and section 18 of CEC have to be marked as follows:

1. Class (optional in Canada)
2. Zone (optional in Canada)
3. Symbol AEx (USA) or Ex or EEx (Canada)
4. Symbol of the type(s) of protection that have been applied
5. Group of the electrical equipment II or gas group(s) IIA, IIB or IIC
6. Temperature class
   Example: Class I Zone 0 AEx ia IIC T6

Russia

Marking of explosion-protected electrical equipment is done according to GOST R 51330.0-99 and according to the standards for the individual types of protection.
Marking of explosion protection contains:

> the level of explosion protection
> Ex-symbol
> symbol of the types of protections that have been applied
> equipment group (I, II or IIA, IIB, IIC)
> temperature class
  symbol X, when special conditions have to be observed for safe use or if the product is an Ex-component.

5. installation and operation of electrical equipment

5. Installation and Operation of Electrical Equipment in Hazardous Areas

5.1 Duties of Installer, Manufacturer and Employer

Safety in potentially explosive areas can only be guaranteed by a close and effective working relationship amongst all parties involved (fig. 7). The employer is responsible for the safety of his installations. It is his duty to verify where there is a risk of explosion and then divide areas into Zones accordingly. He must ensure that the installation is installed in accordance with regulations and that it is inspected before initial use. The installation must be kept in a regular and correct state through periodic inspection and maintenance.

The requirements for the operation of facilities in hazardous areas are defined in national regulations. In Europe the minimum regulations are stipulated in Directive 99/92/EC (ATEX 137). In Germany the Health and Safety at Work Regulations (BetrSichV) must be maintained. They are specifically defined with the different TRBS (technical rules for operational safety) – please also see table 5 on page 14. On an international level and on the European level, different standards have been established which can be used as sources of information in Germany (see table 19). However, this only applies if it does not contradict the German Health and Safety at Work Regulations or a TRBS.

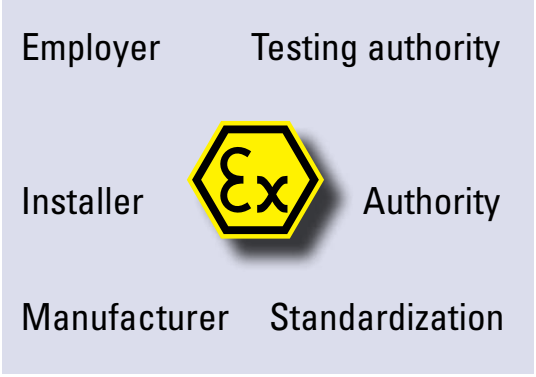


Fig. 7: **Co-operation of all parties involved**

The installer must observe the installation requirements, and select and install the electric apparatus correctly for its intended use. Manufacturers of explosion protected apparatus are responsible for routine testing, certification and documentation and are required to ensure that each device manufactured complies with the approved design.

Table 19: **Explosive atmospheres (gas and combustible dust)**

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

5.2 Classification of Zones and Selection of Apparatus

The question of possible risks of explosion must be addressed at the early stages new facility planning. When classifying potentially explosive areas, the influence of natural or technical ventilation must be considered in addition to the quantity of flammable substances being released. Furthermore, the explosion safety characteristics must be ascertained for the flammable substances being used (see Appendix 7.2). Only then can a decision be reached on the classification of potentially explosive areas into Zones and the selection of suitable apparatus.
Equipment shall only be used within the ambient temperature range stipulated in its marking.

If the marking does not contain any information, the standard range of between –20 °C and +40 °C applies.
Electrical apparatus with the types of protection »d« and »i« must correspond to an explosion group IIA, IIB or IIC. Electrical apparatus must be selected and installed such that it is protected against external influences which may adversely affect the explosion protection measures.

5.3 Methods of Installation

Essentially, three systems are used for electrical installations in hazardous areas:

- 1. Cable system with indirect entry
- 2. Cable system with direct entry
- 3. Conduit system

The technical design of the electrical apparatus used with the individual types of installation is accordingly different.

Only the conduit system or mineral insulated cables (MI) are permitted in the USA for all applications in Class 1, Division 1 in accordance with NEC 501-4, whereby the mineral insulated cables are mainly used as heating lines and fire resistant signal and control lines. Certain types of cable and line are also permitted in Division 2. A comparison of the various systems is shown below.

Cable systems

Cable systems are mainly used in Europe. For this, high-quality cables are laid uncovered. It is only in areas in which mechanical damage could be expected that they are laid in conduits that are open at both ends.

5. installation and operation of electrical equipment

In the case of **indirect** entry, the cables and lines are conducted via cable glands into a connection chamber in the type of protection "Increased Safety" and connected to the terminals also provided in "Increased Safety". From here, the individual wires are conducted via flameproof bushings into the flameproof enclosure.
The cable bushings are installed by the manufacturer, with the result that, by contrast with direct entry, a routine test of the factory wired flameproof enclosure can be made.
The installation engineer need only open the connection chamber for the connection, not the flameproof enclosure.

In the case of **direct** entry, the connecting cables are entered directly into the flameproof enclosure. Only cable glands that have been specially certified for this purpose may be used for this type of entry.

The flexible gasket and the cable sheath must form a flameproof joint through which no flames can penetrate. For this reason, attention must be paid to the appropriate selection of cable gland depending on both the type and structure of cable and installation location. If the flameproof enclosure has to be used in a IIC atmosphere or if a flameproof enclosure with a volume bigger than 2 dm^3 has to be applied in Zone 1, the gaskets or cable glands have to be sealed. The flameproof enclosure primarily depends here on the care taken by the electrician when connecting the cables.

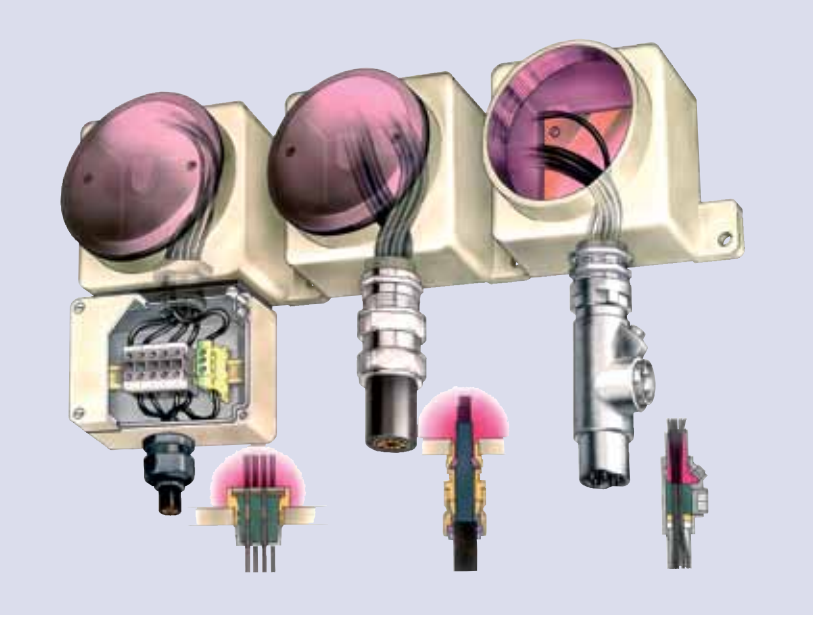


Fig. 8: **Methods of Installation worldwide: Left: Cable system with indirect entry; Centre: Cable system with direct entry; Right: Conduit system**

Conduit System

In the case of installation using the conduit system, the electrical lines are drawn as single wires into enclosed metal conduits. The conduits are connected to the housings by means of fittings and equipped with a seal at each entrance point. The entire conduit system is flameproof. The aim of the seal is to prevent explosions which may occur inside the housing from transmitting into the conduit.
Otherwise, extremely high explosion pressures would be created as a result of precompression in long cylindrical tubes. For this reason, it is recommended that seals be installed not just at the entrance points but at specific intervals. Drains must be installed at low points at which condensate can accumulate.

5.4 Maintenance

Periodic maintenance is required to maintain the safety of electrical installations in hazardous areas. Personnel who carry out such maintenance work should work under the guidance of an explosion protection expert and should be informed of the particular hazards involved (skilled person, IEC 60079-17).

Before corrective maintenance, it must be ensured that there is no danger of explosions occurring during this work. Normally, formal written permission for this should be acquired from the company management. On completion of the work, documentation should be kept of what work was carried out, and confirmation given that all relevant regulations have been observed.

Once work is completed it should be documented what work was done and confirmed that all relevant regulations were adheared to.
In case of overhaul which may impair explosion protection, an examination by a qualified person, acknowledged by the authorities, or an examination by the manufacturer has to be done in Germany (TRBS 1201 part 3).

When replacing components or complete equipment the technical explosion and equipment specifications are to be observed. This inspection may be done by an approved inspection agency.

6. Appendix

6.1 Safety Characteristics of Flammable Gases and Vapours

Table 20: **Safety Ratings: Ignition Temperature, Temperature Class and Explosion Group**

Material	Ignition Temperature °C	Temperature Class	Explosion Group
1,2-Dichloroethane	440	T 2	II A
Acetaldehyde	155	T 4	II A
Acetone	535	T 1	II A
Acetylene	305	T 2	II C [3]
Ammonium	630	T 1	II A
Petrol fuels	220 bis 300	T 3	II A
Benzene	555	T 1	II A
Cyclohexanone	430	T 2	II A
Diesel fuels	220	T 3	II A
Acetic acid	485	T 1	II A
Acetic anhydride	330	T 2	II A
Ethane	515	T 1	II A
Ethyl ethanoate	470	T 1	II A
Ethanol	400	T 2	II B
Ethyl chloride	510	T 1	II A
Ethylene	440	T 2	II B
Ethylene oxide	435 (self-decomposing)	T 2	II B
Diethyl ether	175	T 4	II B
Ethyl glycol	235	T 3	II B
Fuel oil EL, L, M, S	220 to 300	T 3	II A
i-Amyl acetate	380	T 2	II A
Carbon monixide	605	T 1	II A
Methane	595	T 1	II A
Methanol	440	T 2	II A
Methyl chloride	625	T 1	II A
Naphtalene	540	T1	II A
n-Butanol	365	T 2	II A
n-Butanol	325	T 2	II B
n-Hexane	230	T 3	II A
n-Propyl alcohol	385	T 2	II B*
Phenol	595	T 1	II A
Propane	470	T 1	II A
Carbon disulphide	95	T 6	II C [1]
Hydrogen sulphide	270	T 3	II B
Toluene	535	T 1	II A
Hydrogen	560	T 1	II C [2]

* The gas group for this substance has not yes been determined.
[1] Also gas groups II B + CS2 [2] Also gas groups II B + H2 [3] Also gas groups II B + C2 H2

6.2 Constructional Requirements for Explosion Protected Electrical equipment for gas atmospheres

Table 21: **Constructional Requirements in Europe, USA, Canada, and International Compariosn, Part 1**

Type of ignition protection	Abbreviation	Region	Installation location	Standard
General requirements		US	Class I, Division 1 & 2	FM 3600
	AEx	US	Class I, Zone 0, 1 & 2	ISA 60079-0
	Ex	CA	Class I, Zone 0, 1 & 2	CSA E60079-0
	Ex (EEx)	EU	Zone 0, 1 & 2	EN 60079-0
	Ex	IEC	Zone 0, 1 & 2	IEC 60079-0
Increased safety	AEx e	US	Class I, Zone 1	ISA 60079-7
	Ex e	CA	Class I, Zone 1	CSA E60079-7
	Ex e (EEx e)	EU	Zone 1	EN 60079-7
	Ex e	IEC	Zone 1	IEC 60079-7
Non-incendive	(NI)	US	Class I, Division 2	FM 3611
	(NI)	CA	Class I, Division 2	C22.2 No. 213
Non-sparking apparatus	AEx nA	US	Class I, Zone 2	ISA 60079-15
	Ex nA	CA	Class I, Zone 2	CAS E60079-15
	Ex nA (EEx nA)	EU	Zone 2	EN 60079-15
	Ex nA	IEC	Zone 2	IEC 60079-15
Explosion-proof	(XP)	US	Class I, Division 1	FM 3615
	(XP)	CA	Class I, Division 1	C22.2 No. 30
Flameproof enclosure	AEx d	US	Class I, Zone 1	ISA 60079-1
	Ex d	CA	Class I, Zone 1	CSA E60079-1
	Ex d (EEx d)	EU	Zone 1	EN 60079-1
	Ex d	IEC	Zone 1	IEC 60079-1
Powder filling	AEx q	US	Class 1, Zone 1	ISA 60079-5
	Ex q	CA	Class I, Zone 1	CSA E79-5
	Ex q (EEx q)	EU	Zone 1	EN 50017
	Ex q	IEC	Zone 1	IEC 60079-5
Protected facilities and components	AEx nC	US	Class I, Zone 2	ISA 60079-15
	Ex nC	CA	Class I, Zone 2	CSA E60079-15
	Ex nC (EEx nC)	EU	Zone 2	EN 60079-15
	Ex nC	IEC	Zone 2	IEC 60079-15
Intrinsic Safety	(IS)	US	Class I, Division 1	FM 3610
	(IS)	CA	Class I, Division 1	C22.2 No. 157
	AEx ia	US	Class I, Zone 0	FM 3610
	AEx ib	US	Class I, Zone 1	FM 3610
	Ex ia	CA	Class I, Zone 0	CSA E60079-11
	Ex ib	CA	Class I, Zone 1	CSA E60079-11
	Ex ia (EEx ia)	EU	Zone 0	EN 50020
	Ex ib (EEx ib)	EU	Zone 1	EN 50020
	Ex ia	IEC	Zone 0	IEC 60079-11
	Ex ib	IEC	Zone 1	IEC 60079-11

Table 21: **Constructional Requirements in Europe, USA, Canada and International Comparision, Part 2**

Type of ignition protection	Abbreviation	Region	Installation location	Standard
Energy-limited apparatus	AEx nC	US	Class I, Zone 2,	ISA 60079-15
	Ex nL	CA	Class I, Zone 2	CSA E60079-15
	Ex nL (EEx nL)	EU	Zone 2	EN 60079-15
	En nL	IEC	Zone 2	IEC 60079-15
Pressurized enclosure	Type X	US	Class I, Division 1	FM 3620
	Type X	CA	Class 1, Divison 1	NFPA 496
	Type Y	US	Class I, Division 1	FM 3620
	Type Y	CA	Class I, Division 1	NFPA 496
	Type Z	US	Class 1, Division 2	FM 3620
	Type Z	CA	Class 1, Division 2	NFPA 496
	AEx px	US	Class I, Zone 1	ISA 60079-2
		CA	Class I, Zone 1	CSA E60079-2
		EU	Zone 1	EN 60079-2
		IEC	Zone 1	IEC 60079-2
		US	Class I, Zone 1	ISA 60079-2
		CA	Class I, Zone 1	CSA E60079-2
		EU	Zone 1	EN 60079-2
		IEC	Zone 1	IEC 60079-2
		US	Class I, Zone 2	ISA 60079-2
		CA	Class I, Zone 2	CSA E60079-2
		EU	Zone 2	EN 60079-2
		IEC	Zone 2	IEC 60079-2
Purged/pressurized	AEx nR	US	Class I, Zone 2	ISA 60079-15
	Ex nR	CA	Class I, Zone 2	CSA E60079-15
	Ex nR (EEx nR)	EU	Zone 2	EN 60079-15
	Ex nR	IEC	Zone 2	IEC 60079-15
Encapsulation	Ex ma (EEx ma)	EU	Zone 0	EN 60079-18
	Ex ma	IEC	Zone 0	IEC 60079-18
	AEx m	US	Class I, Zone 1	ISA 60079-18
	Ex m	CA	Class I, Zone 1	CSS E60079-18
	Ex mb (EEx mb)	EU	Zone 1	EN 60079-18
	Ex mb	IEC	Zone 1	IEC 60079-18
Oil immersion	AEx o	US	Class I, Zone 1	ISA 60079-6
	Ex o	CA	Class I, Zone 1	CSA E79-6
	Ex o (EEx o)	EU	Zone 1	EN 50015
	Ex o	IEC	Zone 1	IEC 60079-6

6.3 Degrees of Protection according to IEC 60529 – IPXX

Table 22: **Degrees of Protection according to IEC 60529 – IPXX**

Digit	First digit Physical protection	Foreign body protection	Second digit Water protection
0	No protection	No protection	No protection
1	Protection against back of hand contact	Protection against solid foreign bodies 50 mm Ø	Protection against water drops falling vertically
2	Protection agains finger contact	Protection against solid foreign bodies 12,5 mm Ø	Protection against water drops falling at an angle (15°)
3	Protection against contact from tools	Protection against solid foreign bodies 2,5 mm Ø	Protection against water-spray at an angle up to 60°
4	Protection against contact with a wire	Protection against solid foreign bodies 1,0 mm Ø	Protection against water spray from all directions
5	Protection against contact with a wire	Protection against dust	Protection against water jets
6	Protection against contact with a wire	Dust-tight	Protection against strong water jets
7			Protection against intermittent immersion in water
8			Protection against continuous immersion in water

6.4 Degrees of Protection according to NEMA Standards

Table 23: **Degree of Protection provided by Enclosures according to NEMA (Publication No. 250 Enclosures for Electrical LEuqipment 1000 Volts Maximum)**

Digit	Degree of Protection	Use
Type 1	Protection against incidental contact with the enclosed equipment.	Indoor
Type 2	Protection against limited amounts of falling water and dirt.	Indoor
Type 3	Protection against rain, sleet, windblown dust, and damage from external ice formation.	Outdoor
Type 3R	Protection against rain, sleet, and damage from external ice formation.	Outdoor
Type 4	Protection against, rain, splashing water, hose directed water, and damage from external ice formation.	Indoor or outdoor
Type 4X	Protection against, rain, splashing water, hose directed water, and damage from external ice formation. Protection against corrosion.	Indoor or outdoor
Type 5	Protection against settling airborne dust, falling dirt, and dripping non-corrosive liquids.	Indoor
Type 6	Protection against hose directed water, penetration of water during occasional temporary submersion at a limited depth, and damage from external ice formation.	Indoor or outdoor
Type 6P	Protection against hose directed water, penetration of water during prolonged submersion at a limited depth, and damage from external ice formation.	Indoor or outdoor
Type 7	For use in locations classified as Class I, Groups A, B, C or D as defined in the NEC.	Indoor
Type 8	For use in locations classified as Class I, Groups A, B, C or D as defined in the NEC.	Indoor or outdoor
Type 9	For use in locations classified as Class II, Groups E, F, or G as defined in the NEC.	Indoor
Type 10	Constructed to meet the applicable requirements of the Mine Safety Health Administration.	Mining
Type 11	Protection against the corrosive effects of liquids and gases by oil immersion.	Indoor
Type 12, 12K	Protection against circulating dust, falling dirt, and dripping non-corrosive liquids.	Indoor
Type 13	Protection against dust, splashing water, oil, and non-corrosive liquids.	Indoor

7. Literature

Directive 94/9/EU 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. Official Journal of the European Communities, No. L 100/1

The Equipment and Protective Systems for Use in Potentially Explosive Atmospheres Regulations, 1996 (EPS), ATEX 95/(UK).

Directive 99/92/EC on the »Minimum requirements for improving the health and safety protection of the worker at risk from explosive atmospheres« 16/12/1999, Official Journal of the European Communities, L23/57–64

The Dangerous Substances and Explosive Atmospheres Regulations 2002, Statutory Instrument 2002 No. 2776 (UK).

IEC 60079 Part 0 to 31
Explosive atmospheres
www.iec.de/webstore

IEC 61241 Part 0 to 18
Electrical apparatus for use in the presence of combustible dust
www.iec.ch/webstore

EN 60079 Part 0 to 31
Explosive atmospheres
www.cenelec.eu

EN 61241 Part 0 to 18
Electrical apparatus for use in the presence of combustible dust
www.iec.ch/wekstore

EN 60529
Degrees of protection provided by enclosures (IP code)
www.iec.ch/webstore

EN 13463 Part 1 to 8
Non-electrical equipment for potentially explosive atmosphere
www.cen.eu

	Type of protection	standard symbol	alternate symbol	Zone	Main application	Standard
	increased safety	e	eb	1	terminal and junction boxes, cage induction motors, light fittings	IEC 60079-7 EN 60079-7
	flameproof enclosures	d	db	1	switchgear, control stations, motors,	IEC 60079-1 EN 60079-1
	pressurized enclosures	px py pz p	pxb pyb pzc pb pc	1 1 2 21 22	switchgear and control cabinets, analysers, large motors	IEC 60079-2 / IEC 61241-4 EN 60079-2 / EN 61241-4
	intrinsic safety	ia ib ic	ia ib ic	0, 20 1, 21 2	instrumentation technology, field-bus technology, sensors, actuators	IEC 60079-11 / IEC 61241-11 EN 60079-11 / EN 61241-11
	oil immersion	o	ob	1	transformers, starting resistors	IEC 60079-6 EN 60079-6
	powder filling	q	qb	1	sensors, electronic ballasts, electronic devices	IEC 60079-5 EN 60079-5
	encapsulation	ma mb mc	ma mb mc	0, 20 1, 21 2, 22	display units, sensors, electronic devices	IEC 60079-18 / IEC 61241-18 EN 60079-18 / EN 61241-18
	type of protection „n“	n_	n_c	2	electrical apparatus for Zone 2	IEC 60079-15 EN 60079-15
	protection by enclosures	ta tb tc	ta tb tc	20 21 22	switchgear and control station, terminal and connection boxes, control boxes, motors, light fittings	IEC 60079-31 / IEC 61241-1 EN 60079-31 / EN 61241-1

Marking of electrical equipment

mines		
Group I		Methane
explosive gas atmosphere		
Group II	IIA	Propane
	IIB	Ethylene
	IIC	Hydrogene
explosive dust atmosphere		
Group III	IIIA	combustible flyings
	IIIB	non-conductive dust
	IIIC	conductive dust

Type of protection — Group

ATEX-marking — **II 2G Ex db [ia] IIC T6** — max. surface temperature

equipment-group I: mines; equipment-group II: other places

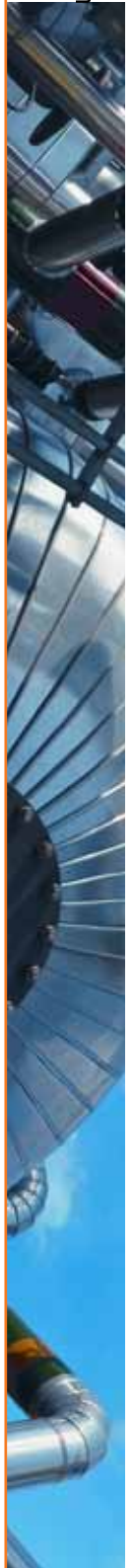
hazardous places	Zone 0	Zone 20	Zone 1	Zone 21	Zone 2	Zone 22	mines
Dangerous explosive atmosphere	continously or long-term or frequently		likely to occur		not likely to occur or for short period		
equipment category	1G	1D	2G	2D	3G	3D	M1 or M2
EPL* (IEC/EN 60079-0)	Ga	Da	Gb	Db	Gc	Dc	Ma or Mb

* when not using the alternate symbols the EPL shall be specified:: e.g. Ex d [iaGa] IIC T6 Gb

explosive gas atmosphere: temperature classes	
450 °C	T1
300 °C	T2
200 °C	T3
135 °C	T4
100 °C	T5
85 °C	T6

explosive dust atmosphere: surface temperature

T ...°C (e.g.: T 80°C)



Marking of non-electrical equipment

	Type of protection	symbols	Zone	Main application	Standard
	constructional safety	c	0, 1, 2 20, 21, 22	couplings, pumps, gear drives, chain drives,belt drives	EN 13463-5
	flameproof enclosures	d	1, 2 21, 22	brakes, couplings	EN 13463-3
	pressurisation	p	1, 2 21, 22	pumps	EN 60079-2
	control of ignition sources	k	0, 1, 2 20, 21, 22	pumps, beld drives	EN 13463-8
	liquid immersion	b	0, 1, 2 20, 21, 22	submerged pumps, gears	EN 13463-6
	flow restricting enclosure	fr	2 22	equipment only for Zone 2 or Zone 22	EN 13463-2

Mines		
Group I		Methane
explosive gas atmosphere		
Group II	IIA	Propane
	IIB	Ethylene
	IIC	Hydrogene

Type of protection — Group

ATEX-marking — max. surface temperature

II 2G c IIC T6

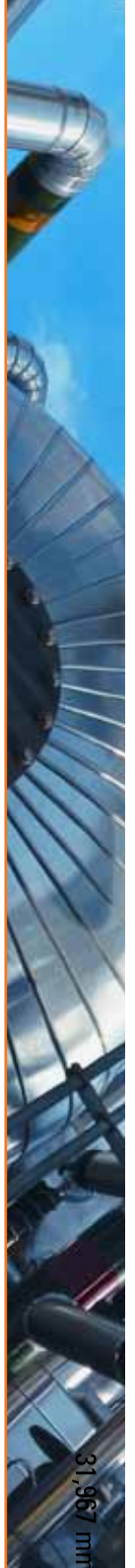
equipment-group I: mines; equipment-group II: other places

hazardous places	Zone 0	Zone 20	Zone 1	Zone 21	Zone 2	Zone 22	mines
Dangerous explosive atmosphere	continously or long-term or frequently		likely to occur		not likely to occur or for short period		
equipment category	1G	1D	2G	2D	3G	3D	M1 oder M2

explosive gas atmosphere: temperature classes	
450 °C	T1
300 °C	T2
200 °C	T3
135 °C	T4
100 °C	T5
85 °C	T6

explosive dust atmosphere: surface temperature

T ...°C (e.g.: T 80°C)



R. STAHL
Am Bahnhof 30, 74638 Waldenburg
Telefon +49 7942 943-0
Telefax +49 7942 943-4333

www.stahl.de

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