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Products and systems for use in hazardous areas

Industrial Automation and Drive Technologies

White paper | October 2018

The EU stipulates binding standards and laws for the use of electrical equipment and systems in hazardous areas.

This white paper "Explosion Protection Fundamentals" provides an overview of the specifications for explosion protection in Germany, Europe, and the U.S. It also serves as a reference manual for decoding device labels.

However, it does not replace intensive study of the relevant fundamentals and guidelines when planning and installing electrical systems.

A white paper from Siemens

Contents

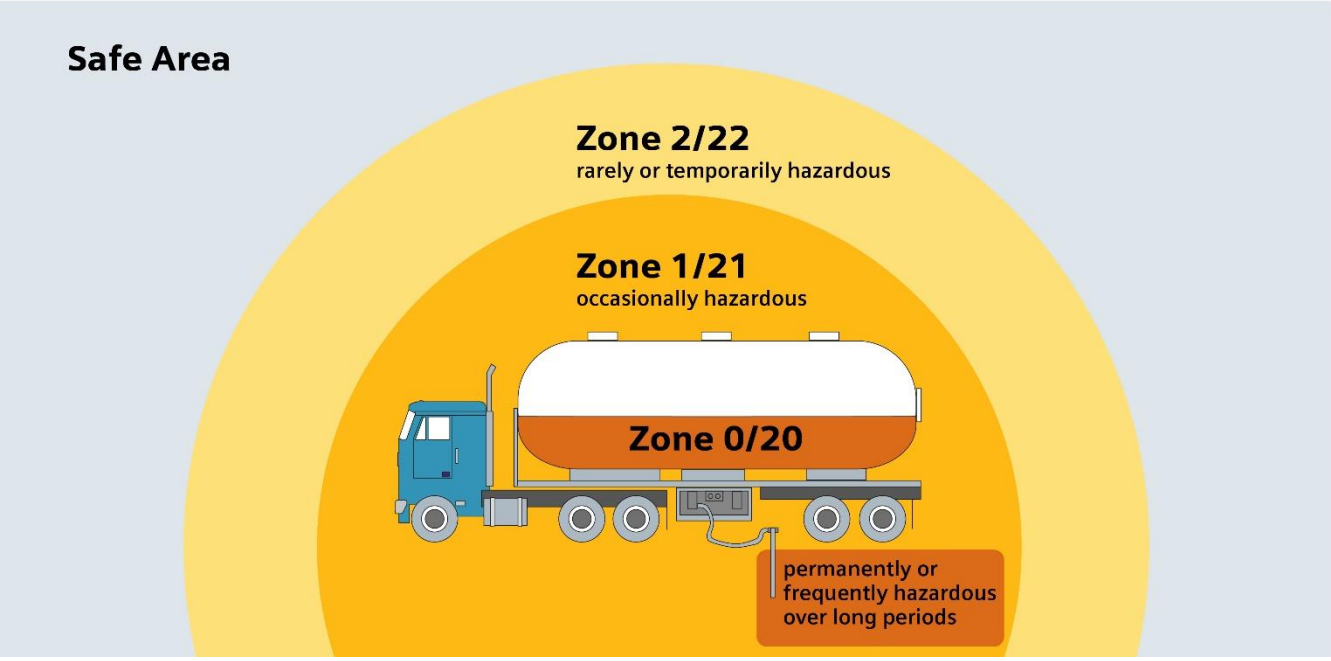
Management summary

Many of the process steps in the manufacture, processing, transport, and storage of combustible materials result in gases, vapors, or mist. These products are often released into the environment, where they can be hazardous for people or materials. Combustible dusts are also hazardous. In conjunction with the oxygen in the air, they can create an explosive atmosphere that results in an explosion if ignited.

These hazards occur particularly in the chemical and petrochemical industries, the transport of crude oil and natural gas, the mining industry, and milling (for example, of grain and other granular solids). However, these threats can also occur in many other branches of industry.

The legislatures of most countries have developed requirements in the form of laws, regulations, and standards in order to guarantee the highest possible level of safety in these areas. In the course of globalization, significant progress has been made toward harmonizing the guidelines for explosion protection.

With Directive 94/9/EC, the European Union has created the prerequisites for complete standardization. As of July 1, 2003, all new devices must be approved in accordance with this directive. It was replaced on April 20, 2016 by the new Directive 2014/34/EU.



Zone definition

Physical principles and parameters

Definition of "explosion"

An explosion is the sudden chemical reaction of a combustible substance with oxygen involving the release of high energy. Combustible substances can be present in the form of gases, mist, vapor, or dust. An explosion can take place only if the following three factors coincide:

- Combustible substance (in the appropriate distribution and concentration)
- Oxygen (in the air)
- Source of ignition (for example, electrical spark)

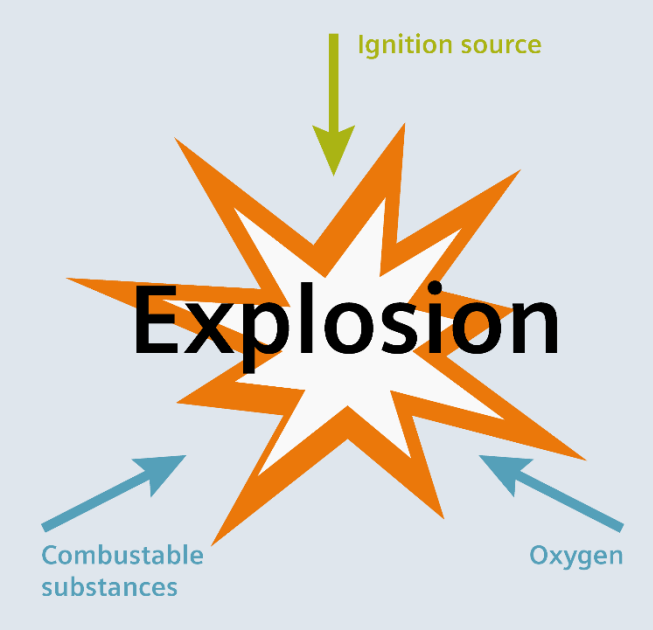
Priority of explosion protection measures

Integrated explosion protection requires measures to be performed in a defined order. A distinction is made here between primary and secondary protection measures. Primary measures have the highest priority.

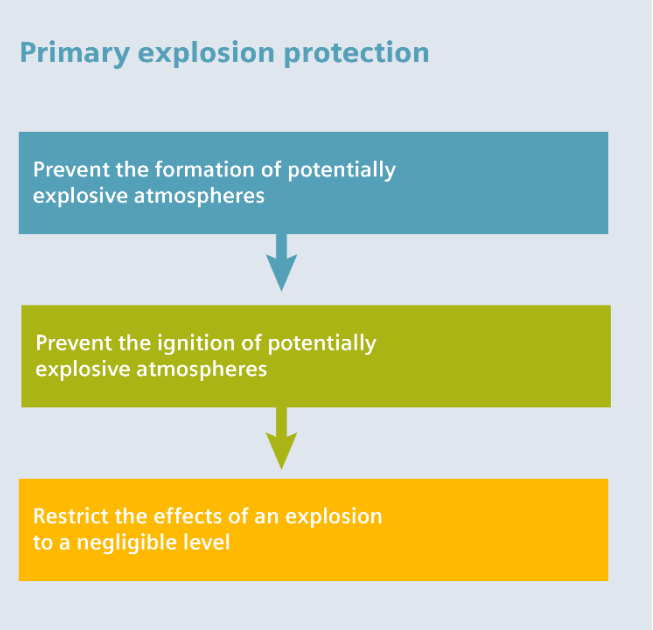
Primary explosion protection prevents the formation of potentially explosive atmospheres. Secondary explosion protection restricts the effects of an explosion to a negligible level but is to be considered only if primary protection is not possible. If a combustible atmosphere can't be reliably prevented, the second priority must be to eliminate sources of ignition.

These protective measures can be taken to minimize the risk of a potentially explosive atmosphere:

- Avoiding combustible substances
- Inerting (addition of nitrogen, carbon dioxide, and other substances)
- Limiting the concentration
- Improving ventilation



Discharge of an explosion



Integrated explosion protection

Safety parameters for the characterization of potential hazards

Flash point

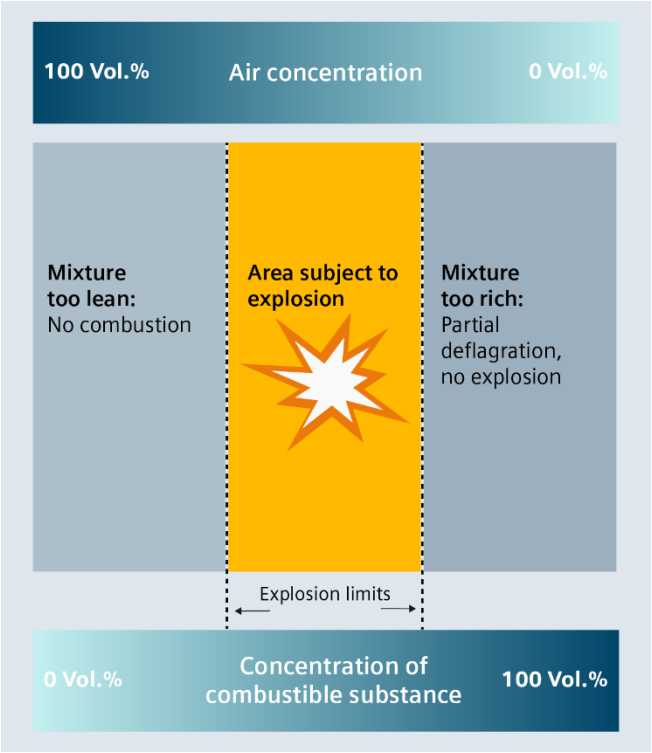
The flash point specifies the lowest temperature at which a vapor/air mixture that can be ignited by a separate source can form over the surface of a flammable liquid. If the flash point is significantly above the maximum prevailing ambient temperature, a potentially explosive atmosphere can't form there. The flash point of a mixture of different liquids can also be lower than the flash point of the individual components.

Explosion limits

Combustible substances can form a potentially explosive atmosphere only within a certain range of concentration.

If the concentration is too low (lean mixture) or too high (rich mixture), an explosion will not take place. Slow burning occurs instead, or no burning at all. Only in the range between the upper and lower explosion limits will the mixture react explosively if ignited.

The explosion limits depend on the surrounding pressure and the proportion of oxygen in the air.



Examples of explosion limits of some common materials

Substance designation	Lower explosion limit	Upper explosion limit
Acetylene	2.3 vol. %	78.0 vol. % (self-decomposing)
Ethylene	2.3 vol. %	32.4 vol. %
Petroleum spirit	Approx. 0.6 vol. %	Approx. 8 vol. %
Benzene	1.2 vol. %	8 vol. %
Natural gas	4.0 (7.0) vol. %	13.0 (17.0) vol. %
Heating oil/diesel	Approx. 0.6 vol. %	Approx. 6.5 vol. %
Methane	4.4 vol. %	16.5 vol. %
Propane	1.7 vol. %	10.9 vol. %
Carbon disulfide	0.6 vol. %	60.0 vol. %
City gas	4.0 (6.0) vol. %	30.0 (40.0) vol. %
Hydrogen	4.0 vol. %	77.0 vol. %

We refer to a deflagration, explosion, or detonation, depending on the speed of combustion.

Even a potentially explosive atmosphere of low volume can result in hazardous explosions in an enclosed space.

Dusts

In industrial environments like the chemical industry and grain mills, solids are frequently encountered in a fine form as dust.

The term "dust" is defined in EN 60079-14 as "small solid particles that can be suspended for some time in the atmosphere but then settle under their own weight (includes dust and coarse dust, as defined in ISO 4225)." Deposits of dust are comparable to a porous body and have a hollow space of up to 90 percent. If the temperature of a dust deposit is increased, the result may be spontaneous ignition of the combustible dust.

If dust with a small particle size is whirled up, there is a risk of explosion. The smaller the particle size, the greater the risk, because the surface area of the hollow space increases. Explosions are frequently the result of whirled-up, smoldering layers of dust that carry the initial spark within them. Explosions of gas/air or vapor/air mixtures can also whirl up dust, in which case the gas explosion can become a dust explosion. In collieries, explosions of methane gas frequently led to explosions of coal dust whose effect was often greater than that of the gas explosion.

The risk of an explosion can be prevented using appropriate explosion-proof devices. The devices are assigned categories that regulate their use in the corresponding hazardous areas.

The potential risk of explosive dust atmospheres and the selection of appropriate protective measures are assessed on the basis of safety parameters described for the materials involved. Dusts are defined according to two material-specific characteristics:

- **Conductivity**
  Dusts are referred to as conductive if they have a specific electric resistance up to 10^3 ohms.
- **Combustibility**
  Combustible dusts can burn or smolder in air. They can form explosive mixtures with air at atmospheric pressure and at temperatures from -20° to +60° Celsius.

The safety parameters for whirled-up dusts are their minimum ignition energy and ignition temperature. For deposited dusts, on the other hand, the smoldering temperature is a characteristic property.

Minimum ignition energy

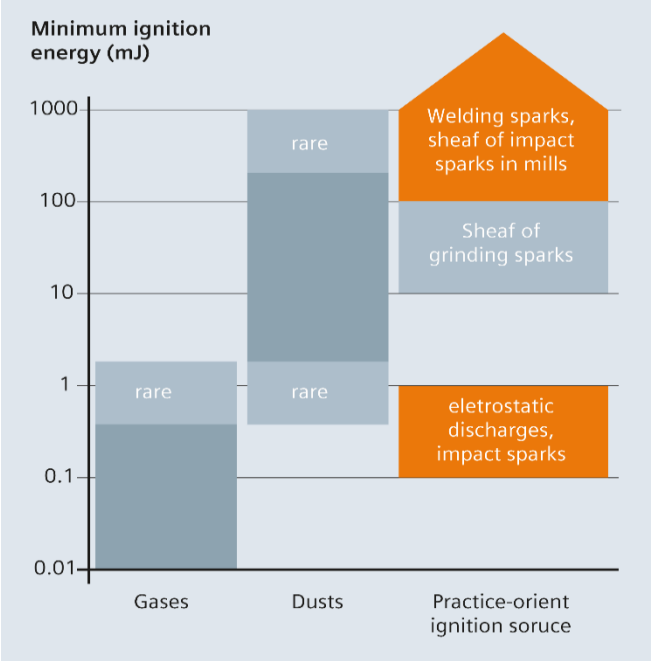
The application of a certain amount of energy is required to ignite a potentially explosive atmosphere. The minimum ignition energy is the least amount of energy necessary to ignite a flammable mixture.

The minimum energy lies between approximately 10^{-5} joules for hydrogen and several Joules for certain dusts.

What can cause ignition?

- Hot surfaces
- Ultrasound
- Ionized radiation
- Open flames
- Chemical reaction
- Optical radiation
- Electromagnetic radiation
- Electrostatic discharge
- Sparks caused mechanically by friction or impact
- Electrical sparks and arcs
- Adiabatic[1)] compression

[1)] An adiabatic state change is a thermodynamic process in which a system is changed from one state to another state without exchanging heat with its surroundings.



Minimum ignition energy of different environments

Legislative basis and standards

Legislative basis of explosion protection

Explosion protection is regulated globally by the legislatures of individual countries. National differences in technical requirements and the required approvals make significant demands on global companies and require considerable overhead in development and approval testing. That's why there have been efforts for some time, particularly among the leading industrial nations, to harmonize the appropriate technical standards and introduce uniform safety standards. Within the European Union, the harmonization process in the area of explosion protection is largely complete.

At the international level, the IEC offers the IECEx Scheme (www.iecex.com) aimed at "a single global test and certificate." Many countries have since accepted IECex as a basis for national approvals.

EU directives/CE mark

In the European Union, explosion protection is regulated by directives and laws. Electrical devices in the EU must satisfy the relevant requirements. The manufacturer can attach the CE mark to a device if these requirements have been fulfilled. Any violations are a punishable offence.

In accordance with the ATEX guideline[1)], the number of the notified office that has conducted the acceptance testing of the quality assurance system – for example, the German national metrology institute in Brunswick (Physikalisch Technische Bundesanstalt in Braunschweig) – is added to the CE mark. In the EU, the ATEX guideline is also applied to non-electrical equipment like pneumatic drives.

If systems and equipment have been classified as requiring monitoring, only approved devices may be used. Furthermore, commissioning, changes, and regular safety inspections must be performed by registered institutes or authorized companies. The EU directives are binding for all Member States and form the legal framework.

Important EU directives

Abbreviation	Full text	Directive No.	Valid since
Low-voltage directive	Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonization of the laws of Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits (recast)	2014/35/EU	20 April 2016
EMC directive	Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonization of the laws of Member States relating to electromagnetic compatibility (recast)	2014/30/EU	20 April 2016
Machinery directive	Directive 2006/42/EG of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EG (recast)	2006/42/EC	29 June 2006
ATEX directive	Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonization of the laws of Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast)	2014/34/EU	20 April 2016
Pressure directive	Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonization of the laws of Member States relating to the making available on the market of pressure equipment (recast)	2014/68/EU	20 April 2016
ATEX 137 (old: ATEX 118a)	Minimum requirements for the improvement of the health protection and the safety of workers, which could be endangered by the explosive atmosphere	1999/92/EG	16 December 1999[2)]

[1)] ATEX is the abbreviation for ATmosphaére EXplosible
[2)] The transitional regulations are defined in the relevant national legislation. In Germany, this is the working reliability regulation (BetrSichV).

National laws and regulations

In general, EU directives are European law that must be incorporated by the individual member states unmodified and "one-to-one" by ratification. Directive RL 2014/34/EU was completely adopted into the German explosion protection regulation ExVO. The underlying legislation for technical equipment is the Equipment Safety Law (GSG) to which the ExVO is appended as a separate regulation (11. GSGV).

In contrast, ATEX 137 (Directive 1999/92/EC) contains only "minimum regulations for improving the health protection and safety of employees who could be endangered by potentially explosive atmospheres." This allows each EU Member State to define its own regulations beyond the minimum requirements. In the Federal Republic of Germany, the contents of the directive have been implemented in the working reliability regulation.

Explosion-Protection Guidelines (EX-RL) of the Employer's Liability Insurance Associations

In the "Guidelines for the prevention of hazards from potentially explosive atmospheres with listed examples" for the Employer's Liability Insurance Association (chemicals), specific information is provided on the hazards of potentially explosive atmospheres, and measures for their prevention or limitation are listed. Of special value are the examples of specific potentially explosive process plants in diverse industrial sectors, for which these measures are listed in detail.

Valuable suggestions and risk evaluations are available for planners and owners of comparable process plants. While the EX-RL guidelines have no legal standing, they are nevertheless important recommendations that can also be called on for deciding legal questions in the event of damage.

Standards

There are numerous technical standards worldwide in the area of explosion protection. The standards environment is subject to constant modification due to adaptations to technological progress and increased safety demands. International efforts at standardization also contribute to the goal of achieving uniform global standards and the resulting removal of barriers to trade.

EU standards

The standards for explosion protection valid in the European Union are created on the basis of the EU directives under the leadership of CENELEC (European Committee for Electrotechnical Standardization). The national committees of participating countries are members of CENELEC. Standardization at the international level through the IEC (International Electronic Commission) has acquired significant importance. Therefore, CENELEC has decided to define standards only in parallel with the IEC. In practice, this means that European standards in the area of electrical/electronic systems will now be created or redefined almost exclusively on the basis of IEC standards as harmonized EN standards. In the area of explosion protection, this primarily affects the EN 60079 standards series.

The numbers of the harmonized European standards are structured according to the following system:

Example				Meaning
EN	**60079-0**	**:**	**2014**	Year of issue
				Number of standard
				Harmonized European standard

The IEC issues standards for explosion protection at the international level. Technical Committee TC31 is responsible. IEC standards are also the basis for IECEx certification. Standards for explosion protection are found in the IEC 60079-x series. The "x" represents the number of the specific technical standard, such as IEC 60079-11 for intrinsic safety.

Classification of explosion-proof equipment

Marking

The marking of electrical equipment for use in explosion-proof areas provides information on:

- The vendor of the equipment
- A designation for identification
- The area of use
  - Below ground I
  - Other areas II
- Gases and vapors (G), dusts (D), or mines (M)
- Approval categories for specific zones
- Types of protection
- Identification of the certificate, provided that it was issued by a testing agency.
  This identification includes the symbol of the testing agency, the year of issue of the certificate, ATEX, and a consecutive number. The identification is defined by the testing station and is also recorded on the associated certificate.
- In addition, all the data usually required for a comparable device of industrial design must be provided.

Example of identification according to 94/9/EC				
CE	0344	II 2G	Ex ia IIC	T4
				Temperature class
			Indication of the type(s) of protection with which the equipment complies	
		Representation of the application area		
	Named authority for certification of the QA system according to 2014/34/EU			
Conformity marking				

Example of a device identification				
EXAMPLE COMPANY type 07-5103-.../... Identification of vendor and type				
Ex II 2G Ex ia IIC T4 Type(s) of protection and temperature class				
	KEMA	00	ATEX	1081 Consecutive number of testing agency
				Mandatory indication that the certificate can be used to verify compliance with the ATEX Directive 94/9/EC.
			Year of issue of the certificate	
		Symbol of testing authority		

Equipment groups/categories

In the context of explosion protection, devices are assigned to equipment groups. Each equipment group contains equipment that is in turn assigned to different categories (according to Directive 2014/34/EU). The category specifies the zone where the equipment may be used.

Equipment group I (underground workings, mines and above-ground workings)			
Category	M1: Extremely high level of safety	M2: High level of safety	
Level of danger	Continuous, long-term and frequent danger	Occasional danger	Infrequent and short-term danger
Sufficient safety	Through 2 protective measures/in the event of 2 faults	Must be switched off in the presence of an Ex atmosphere.	

Equipment group II (other areas subject to explosion hazard)					
Category	1: Extremely high level of safety		2: High level of safety		3: Normal level of safety
Danger level	Continuous, long-term and frequent danger		Occasional danger		Infrequent and short-term danger
Sufficient safety	Through 2 protective measures/in the event of 2 faults		In the case of frequent device faults/in the case of one fault		In the case of fault-free operation
Use in	Zone 0	Zone 20	Zone 1	Zone 21	Zone 2	Zone 22
Atmosphere	G (gas)	D (dust)	G	D	G	D

Zones

Hazardous areas are divided into zones. Division into zones depends on the chronological and geographical probability of a hazardous and potentially explosive atmosphere.

EN 60079-10 provides information on the specifications for zone subdivision.

Equipment in permanently hazardous areas (Zones 0/20) is subject to stricter requirements and equipment in less hazardous areas (Zones 1/21, Zones 2/22) is subject to less stringent requirements.

Flammable gases, vapors and mist		
Zone	**Category and atmosphere**	**Description**
0	1G	Hazardous, potentially explosive atmosphere is present **continuously** and over **extended** periods.
1	2G 1G	It is to be expected that a hazardous, potentially explosive atmosphere will occur **occasionally**.
2	3G 2G 1G	It is to be expected that a hazardous, potentially explosive atmosphere will occur **only rarely** and then **only for a short** period.

Flammable dusts		
20	1D	Areas where a potentially explosive atmosphere comprising dust/air mixtures is present **continuously, over extended periods, or frequently**.
21	2D 1D	Areas where it is expected that a hazardous, potentially explosive atmosphere comprising dust/air mixtures will **occur occasionally and for short periods**.
22	3D 2D 1D	Areas where it is not to be expected that a potentially explosive atmosphere will be caused by whirled-up dust. If this does occur, then in all probability only **rarely** and for a short period.

Equipment protection level (EPL)

An alternative procedure for the assignment of Ex equipment to hazardous areas is the system of Equipment Protection Level (EPL): for example, in accordance with IEC 60079-26.

Equipment group I (for devices in underground operations of mines, as well as the above-ground systems that could be endangered by pit gas and/or flammable dusts)		
Equipment protection level EPL	Ma	Mb
Requirement	Very high protection level	High protection level
Sufficient safety	During a gas eruption (if the device remains in operation)	In the time between the gas eruption and the switching off of the device

Equipment group II (for devices in the other hazardous areas)						
Equipment protection level EPL (G = gas, D = dust)	Ga	Da	Gb	Db	Gc	Dc
Requirement	Very high protection level		High protection level		Increased protection level	
Sufficient safety	During proper operation, in the event of anticipated faults and rarely occurring faults		During proper operation, in the event of anticipated faults and those which are not necessarily normal		During proper operation, no ignition source occurs during events which can be regularly anticipated.	
Use in	Zone 0	Zone 20	Zone 1	Zone 21	Zone 2	Zone 22

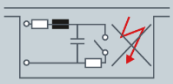
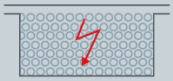
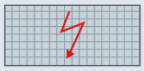
Protection types

The protection types are design measures and electrical measures applied directly to the equipment in order to achieve explosion protection in hazardous areas. Protection types are secondary explosion protection measures.

The scope of the secondary measures depends on the probability of the occurrence of a hazardous and potentially explosive atmosphere.

Electrical equipment for hazardous areas must comply with the general requirements of EN 60079-0 and the specific requirements for the type of protection relevant to the equipment.

The types of protection listed below are significant according to EN 60079-0. All types of protection are based on different protection concepts.

Protection types for electrical equipment in explosive gas atmospheres						Use in Zone/ equipment protection level		
Type of protection	K[1)]		Basic principle	Standard	Examples	0 Ga	1 Gb	2 Gc
General requirements			General requirements for the type and testing of electrical equipment intended for the Ex area	EN 60079-0 IEC 60079-0 ANSI/UL 60079-0 FM 3600				
Increased safety	e		Applies only to equipment, or its component parts, that normally does not create sparks or arcs, does not attain hazardous temperatures, and whose mains voltage does not exceed 1 kV	EN 60079-7 IEC 60079-7 ANSI/ISA/ UL 60079-7	Terminals, terminal boxes		■	■
Flameproof enclosure	d		If an explosion occurs inside the enclosure, the housing will withstand the pressure and the explosion will not be propagated outside the enclosure	EN 60079-1 IEC 60079-1 ANSI/ISA/ UL 60079-1 FM 3615	Switchgear, transformers		■	■
Pressurized enclosure	p		The ignition source is surrounded by a pressurized protective gas (min. 0.5 mbar) – the surrounding atmosphere cannot enter	EN 60079-2 IEC 60079-2 FM 3620 NFPA 496	Control cabinets, switchgear cabinets		■	■
Intrinsic safety	i		By limiting the energy in the circuit, the formation of impermissibly high temperatures, sparks, or arcs is prevented	EN 60079-11 IEC 60079-11 ANSI/ISA/ UL 60079-11 FM 3610	Actuators, sensors,	■	■	■
Oil immersion	o		Equipment or equipment parts are immersed in oil and thus separated from the Ex atmosphere	EN 60079-6 IEC 60079-6 ANSI/ISA/ UL 60079-6	PROFIBUS DP RS 485-iS		■	■
Sand filling	q		Ignition source is buried in sand. The Ex atmosphere surrounding the housing cannot be ignited by an arc	EN 60079-5 IEC 60079-5 ANSI/ISA/ UL 60079-5	Transformers, switching devices		■	■
Encapsulation	m		By encapsulation of the ignition source in a molding, it cannot ignite the Ex atmosphere	EN 60079-18 IEC 60079-18 ANSI/ISA/ UL 60079-18	Strip heaters, capacitors	■	■	■
Types of protection	n		Slightly simplified application of the other protection types – "n" stands for "non-igniting"	EN 60079-15/2/18/11 IEC 60079-15/2/18/11 ANSI/ISA/ UL 60079-15 FM 3611	Sensors, switching devices			■
Optical radiation	op		Suitable measures prevent a hazardous atmosphere from being ignited by optical radiation.	EN 60079-28 IEC 60079-28	Programmable controllers	■	■	■

Protection types for electrical equipment in areas with combustible dust					Use in Zone/ equipment protection level		
Type of protection	**Marking**	**Basic principle**	**Standard**	**Examples**	20 Da	21 Db	22 Dc
General requirements		General requirements for the type and testing of electrical equipment intended for the Ex area	EN 60079-0 IEC 60079-0				
Pressurized enclosure	pD	The penetration of a surrounding atmosphere into the enclosure of electrical equipment is prevented in that a protective gas (air, inert gas or other suit- able gas) is kept within the enclosure at a pressure higher than the surrounding atmosphere	EN 60079-2 IEC 60079-2	Equipment where sparks, arcs or hot components occur during normal operation		■	■
Encapsulation	mD	Parts which could ignite a potentially explosive atmosphere through sparks or heating are encapsulated in a potting compound such that the explosive atmosphere cannot ignite. This is achieved by completely covering the components with a potting compound that is resistant to physical (particularly electrical, thermal and mechanical) and chemical influences.	EN 60079-18 IEC 60079-18	Large machines, slip ring or collector motors, switchgear and control cabinets		■	■
Protection by enclosure	tD	The enclosure is sealed so tight that no combustible dust can penetrate into it. The surface temperature of the external enclosure is limited.	EN 60079-31 IEC 60079-31	Measuring and monitoring systems	■	■	■
Intrinsic safety	iaD, ibD, icD	Current and voltage are limited such that intrinsic safety is guaranteed. No sparks or thermal effects can ignite a dust/air mixture.	EN 60079-11 IEC 60079-11	Sensors and actuators	■	■	■

Explosion groups

In the explosion groups for equipment, a distinction is made between equipment belonging to Group I and Group II according to IEC 60079-1 and -2:

Electrical equipment belonging to Group I is used for mines subject to fire-damp.

Electrical equipment belonging to Group II is subdivided into explosion groups. The division depends on the safety gap and the minimum ignition-current ratio.

Electrical equipment with approval for explosion group IIC can also be used in explosion groups IIA and IIB. Electrical equipment belonging to equipment group III is also classified in additional explosion groups.

Explosion groups					
Equipment group	**Use**	**Explosion group**	**Safety gap for flameproof enclosure**	**Degree of hazard**	**Equipment requirements**
Group I	Electrical equipment for mines subject to fire-damp. ==> fire-damp protection EEx...I				
Group II	Electrical equipment for areas endangered by explosive gases. ==> Explosion protection Ex...II	IIA	> 0.9 mm		
		IIB	0.5 mm to 0.9 mm		
		IIC	< 0.5 mm		
Group III	Electrical equipment for areas endangered by explosive gases. ==> Explosion protection Ex...III	IIIA			
		IIIB			
		IIIC			

Safety parameters

Temperature classes

The ignition temperature of flammable gases or of a flammable liquid is the lowest temperature of a heated surface at which the gas/air or vapor/air mixture ignites.

For this reason, the highest surface temperature of any equipment must always be lower than the ignition temperature of the surrounding atmosphere.

Temperature classes T1 to T6 apply to electrical equipment belonging to explosion group II. Equipment is assigned to each temperature class according to its maximum surface temperature.

Temperature class	Maximum surface temperature of the equipment	Ignition temperatures of combustible substances
T1	450°C	> 450°C
T2	300°C	> 300°C
T3	200°C	> 200°C
T4	135°C	> 135°C
T5	100°C	> 100°C
T6	85°C	> 85°C

Equipment in a higher temperature class can also be used for applications with a lower temperature class. Flammable gases and vapors are assigned to the relevant temperature class based on their ignition temperature.

Flammable gases and vapors

Substance designation	Ignition temperature	Temperature class
1,2-dichloroethane	440°C	T2
Acetaldehyde	140°C	T4
Acetone	540°C	T1
Acetylene	305°C	T2
Ammonia	630°C	T1
Petroleum spirit, gasoline, Initial boiling point < 135°	220 to 300°C	T3
Benzene (pure)	555°C	T1
Cyclohexanone	430°C	T2
Diesel fuels (DIN 51601)	220 to 300°C	T3
Jet fuel	220 to 300°C	T3
Acetic acid	485°C	T1
Acetic acid anhydride	330°C	T2
Ethane	515°C	T1
Ethyl acetate	460°C	T1
Ethyl alcohol	425°C	T2
Ethyl chloride	510°C	T1
Ethylene	425°C	T2
Ethylene oxide	440°C (self-decomposing)	T2
Ethyl ether	170°C	T4
Ethylene glycol	235°C	T3
EL heating oil (DIN 51603)	220 to 300°C	T3
L heating oil (DIN 51603)	220 to 300°C	T3
M and S heating oils (DIN 51603)	220 to 300°C	T3
i-amyl acetate	380°C	T2
Carbon monoxide	605°C	T1
Methane	595 (650)°C	T1
Methanol	455°C	T1
Methyl chloride	625°C	T1
Naphthalene	540°C	T1
n-butane	365°C	T2
n-butyl alcohol	340°C	T2
n-hexane	240°C	T3
n-propyl alcohol	405°C	T2
Oleic acid	360°C (self-decomposing)	T2
Phenol	595°C	T1
Propane	470°C	T1
Carbon disulfide	95°C	T6
Hydrogen sulfide	270°C	T3
Special petroleum spirits, initial boiling point < 135°C	200 to 300°C	T3
City gas (illuminating gas)	560°C	T1
Tetralin (tetrahydronaphthalene)	425°C	T2
Toluene	535°C	T1
Hydrogen	560°C	T1

Flammable dusts

A distinction is made between deposited dusts and whirled-up dusts, because dusts in these forms differ in terms of their smoldering and ignition temperatures.

For equipment selection, it must be ensured according to IEC 60079-14 that the maximum surface temperature of the equipment still guarantees a safety gap relative to the smaller of the two values.

Temperature classes are not defined for dusts, meaning that a specific type of dust must always be assumed.
The smoldering and ignition temperatures of a specific type of dust can be determined from comprehensive tables (for example, Chemsafe). Specialized laboratories also determine the values on request.

Dust from natural products	Ignition temperature	Smoldering temperature
Cotton	420°C	295°C
Wood dust	500°C	290°C
Fodder concentrate	450°C	245°C
Grain	440°C	300°C
Soya	350°C	290° C
Tobacco	300°C	295°C
Starch	420°C	290°C

Dust from technical/chemical products	Ignition temperature	Smoldering temperature
Polyester	560°C	
Rubber	570°C	
Washing agent	330°C	
Polyethylene	360°C	
Polyvinyl acetate	500°C	340°C
Aluminum	530°C	280°C
Magnesium	610°C	410°C
Sulfur	280°C	280°C

Installing and operating electrical systems in hazardous areas

Standards

The installation and construction regulations specified in EN 60079-14 apply, as do all relevant national regulations.

Installation

Three different installation systems are used for electrical systems in hazardous areas.

Installation systems in hazardous areas		
Cable systems with indirect cable inlet	**Cable systems with indirect cable inlet**	**Cable systems with indirect cable inlet**
The cables are inserted into the connection area of the protection type "Increased safety" via cable inlets and connected to the terminals. The terminals also have protection type "Increased safety".	The cables are run direct into the device installation areas. Only cable glands specially certified for this purpose can be used.	The electrical cables are fed into the closed metal piping as single cores. The piping is connected to the housing using glands and provided with a seal at every inlet point. The entire piping system is flameproof in design. The piping system is also known as a *conduit* system.

Service and maintenance

Regular servicing is required to maintain the safety of electrical systems in hazardous areas.

Important safety measures

- Performing work on live electrical systems and equipment is prohibited in hazardous areas. Work on intrinsically safe circuits is a permissible exception.
- In hazardous areas, grounding or short-circuiting is permissible only if there is no danger of explosion.
- In the case of all work conducted in hazardous areas, there must be no possibility of ignitable sparks or excessively hot surfaces occurring that could cause an explosion in conjunction with a potentially explosive atmosphere.

Service and maintenance principles for the plant operator

- **Maintenance** of the proper condition of the system
- **Continuous monitoring** of the electrical system
- Immediate execution of the necessary **maintenance activities**
- **Proper operation** of the system
- **Cessation of operations** in the case of unrectifiable faults that can constitute a hazard to personnel

Intrinsic safety

The intrinsic safety of a circuit is achieved by limiting the current and voltage. This characteristic limits the "intrinsic safety" type of protection to circuits with relatively low power. Applications include, for example, measuring and control technologies.

The "intrinsic safety" protection type is based on the fact that a certain minimum ignition energy is required to ignite a potentially explosive atmosphere. In an intrinsically safe circuit, no sparks or thermal effects occur during operation or in the event of a fault that could ignite a potentially explosive atmosphere.

Protection level of intrinsically safe equipment

Intrinsically safe electrical equipment and intrinsically safe parts of associated equipment are assigned to protection levels depending on the safety requirements applied when the equipment was designed.

Isolating amplifiers and isolating transformers

Isolating amplifiers and isolating transformers between the intrinsically safe and non-intrinsically safe circuits of the equipment provide the voltage and current limiting necessary for use in hazardous areas. Isolating amplifiers and isolating transformers can be designed as separate equipment or integrated in the modules.

Maintaining intrinsic safety

All devices in an intrinsically safe circuit must meet the requirements of a specific intrinsically safe type of protection. When wiring the components in this circuit (typically transmitters, sensors, and wiring), the characteristic electrical values must be maintained.

Terms and definitions for intrinsic safety	
Intrinsically safe circuit	A circuit in which no spark and no thermal effect can cause the ignition of a potentially explosive atmosphere.
Intrinsically safe electrical equipment	All circuits of the electrical equipment are intrinsically safe. The voltage and current in the intrinsically-safe circuit are low enough such that a short-circuit, interruption or short-circuit to ground will not ignite the potentially explosive atmosphere. Intrinsically-safe electrical equipment is suitable for operation direct in the hazardous area. Typical marking: Ex ib IIC
Associated electrical equipment	At least one circuit of the associated electrical equipment is intrinsically safe. Actuators and sensors connected to this intrinsically-safe circuit can be located in the hazardous area. However, the associated electrical equipment must not be located in the hazardous area without further protection types. In the marking of associated electrical equipment, the type of protection is placed in brackets. Typical marking: [Ex ib] IIC
Minimum ignition energy	The minimum ignition energy of a gas and a vapor/air mixture is the smallest possible electrical energy discharged by a capacitor that can ignite the most ignitable mixture of a gas or a vapor with air at atmospheric pressure and 20°C.

Safety level of intrinsically-safe equipment	Description	Installation of the equipment	
ia	The intrinsically-safe electrical equipment must not cause an ignition • During normal operation • When a single fault occurs • When a combination of faults occurs	Gas Up to Zone 0	Dust Up to Zone 20
ib	The intrinsically-safe electrical equipment must not cause an ignition • During normal operation • When a single fault occurs	Up to Zone 1	Up to Zone 21
ic	The intrinsically-safe electrical equipment must not cause an ignition during normal operation.	Zone 2	Zone 22

Explosion protection in North America

The basic principles of explosion protection are similar all over the world. However, the electrical devices, techniques, and systems that have been developed in North America in the area of explosion protection differ significantly from IEC (International Electrotechnical Commission) standards.

The differences include the division of hazardous areas, design, and requirements for installing electrical systems.

Classification of hazardous areas

Areas subject to explosion hazard are termed "hazardous (classified) locations" in North America. In the U.S., they are defined in Sections 500 to 506 of the National Electrical Code (NEC), and in Canada they are defined in Section 18 and Annex J of the Canadian Electrical Code (CEC). They encompass areas where flammable gases, vapors, or mist (Class I), dusts (Class II), or fibers and threads (Class III) can be present in hazardous quantities.

The hazardous areas are traditionally divided into Division 1 and Division 2 based on the frequency and duration of their occurrence.

In the U.S., the IEC classification system was also introduced for Class I. This change was made in Article 505 of the NEC, enabling users to select the optimal system from a technical and economic standpoint.

The IEC Zone concept was also introduced in Canada. All newly installed systems there must be classified according to this system.

In the North American classification system, potentially explosive gases, vapors, and mist in Class I are assigned to Gas Groups A, B, C, and D, and flammable dusts in Class II are assigned to Groups E, F, and G. The letter A indicates the most hazardous gas group whereas – according to IEC and the new classification in accordance with Article 505 – Group C is the most hazardous gas group.
Determination of the maximum device surface temperature in accordance with Article 505 in the NEC is in agreement with IEC in six temperature classes T1 to T6, with an additional division into temperature subclasses in the division system.

Degrees of protection provided by enclosures

Corresponding to IEC 60529, which defines the IP degrees of protection for enclosures, the U.S. has the UL 50 Standard, among others. These degrees of protection can't be precisely equated with those of the IEC because NEMA takes into account additional environmental influences (for example, coolants, cutting coolants, corrosion, icing, hail).

The following table is therefore a non-binding guideline:

Degrees of protection according to NEMA	Degrees of protection according to IEC
1	IP10
2	IP11
3	IP54
3R	IP14
3S	IP54
4 and 4X	IP56
5	IP52
6 and 6P	IP67
12 and 12K	IP52
13	IP54

Note
Because the degree of protection requirements in UL 50 correspond to, or are higher than, the IP degrees of protection in the IEC, the table can't be used to convert the IEC degrees of protection into corresponding UL 50 degrees of protection.

Classification of hazardous areas				
Gases, vapors, or mist Classification Class I		**Dusts Classification Class II**		**Fibers and threads Classification Class III**
Division system	**Zone system**	**Division system**	**Zone system**	**Division-System**
NEC 500.5 (B) CEC J18-004	NEC 505.5 (B) CEC 18-006	NEC 500.5 (C) CEC J18-006	NEC 506.5 (B) CEC 18-008	NEC 500.5 (D) CEC J18-008
Division 1 Areas in which hazardous concentrations of flammable gases, vapors, or mist are continuously or occasionally present under normal operating conditions.	Zone 0 Areas in which hazardous concentrations of flammable gases, vapors, or mist are present continuously or over long periods under normal operating conditions.	Division 1 Areas in which hazardous concentrations of flammable dusts are continuously or occasionally present under normal operating conditions.	Zone 20 Areas in which ignitable concentrations of flammable dusts or ignitable fibers or threads are present continuously or over long periods under normal operating conditions.	Division 1 Areas in which hazardous concentrations of flammable fibers and threads are continuously or occasionally present under normal operating conditions.
	Zone 1 Areas in which hazardous concentrations of flammable gases, vapors, or mist are present occasionally under normal operating conditions.		Zone 21 Areas in which ignitable concentrations of flammable dusts or ignitable fibers or threads are occasionally present under normal operating conditions.	
Division 2 Areas in which ignitable concentrations of flammable gases, vapors, or mist are not expected under normal operating conditions.	Zone 2 Areas in which ignitable concentrations of flammable gases, vapors, or mist are not expected under normal operating conditions.	Division 2 Areas in which ignitable concentrations of flammable dusts are not expected under normal operating conditions.	Zone 22 Areas in which ignitable concentrations of flammable dusts or ignitable fibers or threads are not expected under normal operating conditions.	Division 2 Areas in which easily ignitable fibers or threads are stored or handled outside a manufacturing process.

Material groups				
Class I		**Class II**		**Class III**
NEC 500.6 (A) CEC J18-050	NEC 505.6 CEC 18-050	NEC 500.6 (B) CEC J18-050	NEC 500.6 CEC 18-050	
Divisions 1 and 2 A (acetylene) B (hydrogen) C (ethylene) D (propane)	Zones 0, 1, and 2 IIC (acetylene + hydrogen) IIB (ethylene) IIA (propane)	Divisions 1 and 2 E (metal dust) F (coal dust) G (grain dust)	Zones 20, 21, 22 IIIC (metal dust) IIIB (dust other than metal dust) IIIA (solid particle and fibers > 0.5mm)	Divisions 1 and 2 None

Temperature classes				
Class I Divisions 1 and 2	**Class I Zones 0, 1, and 2**	**Class II Divisions 1 and 2**	**Class II Zones 20, 21, and 22**	**Class III Divisions 1 and 2**
T1 (≤ 4 50°C)	T1	T1	T1	None
T2 (≤ 300°C) T2A (≤ 280°C) T2B (≤ 260°C) T2C (≤ 230°C) T2D (≤ 215°C)	T2 –	T2 T2A, T2B, T2C, T2D	T2 –	
T3 (≤ 200°C) T3A (≤ 180°C) T3B (≤ 165°C) T3C (≤ 160°C)	T3 –	T3 T3A, T3B, T3C	T3 –	
T4 (≤ 135°C) T4A (≤ 120°C)	T4 –	T4 T4A	T4 –	
T5 (≤ 100°C)	T5	T5	T5	
T6 (≤ 85°C)	T6		T6	

Installation requirements

Electrical equipment and systems for use in hazardous locations are covered by the National Electrical Code (NEC) in the U.S. and by the Canadian Electrical Code (CEC) in Canada. These codes constitute the installation regulations for electrical systems in all areas and refer to a number of other standards from other institutions that contain regulations for the installation and construction of appropriate equipment.

Construction requirements

The regulations of the National Electrical Code and the Canadian Electrical Code specify what equipment or types of protection can be used in the individual hazardous areas.

In North America, different standards and regulations apply to the construction and testing of explosion-proof electrical systems and equipment. In the U.S., these are primarily the standards of the Underwriters Laboratories Inc. (UL), Factory Mutual Research Corporation (FM), and the International Society for Measurement and Control (ISA). In Canada, it is the Canadian Standards Association (CSA).

Certification and designation

In the U.S. and Canada, electrical equipment and resources in workplaces subject to explosion hazard generally require approval. Electrical equipment that can't ignite the potentially explosive atmosphere by virtue of its design or special properties is an exception to this rule. The responsible authority decides whether approval is required.

Equipment for use in hazardous areas is tested and approved in the U.S. and Canada by nationally recognized testing agencies. In the U.S., these include the testing agencies of the Underwriters Laboratories or Factory Mutual, and in Canada, the Canadian Standards Association. The UL and FM testing agencies can also issue approvals for Canada.

All basic information relating to explosion protection must be shown in the marking on the equipment, along with information such as manufacturer name, model, serial number, and electrical specifications. The requirements for this are specified in the NEC, the CEC, and in the relevant construction regulations of the testing agencies.

Approval and testing centers

European inspection bodies

A complete and current list can be viewed on the Internet sites of the EU:

http://www.ec.europa.eu/