Explosion protection

Theory and practice

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Explosive atmospheres can occur in almost all industrial applications. At the same time, the safety of people and production processes as well as a clean environment are important corporate goals worldwide.

Therefore, explosion protection is not just an issue in traditional systems in the chemical and petrochemical industry.

Process industry

Food industry

Machine building and systems manufacturing

Infrastructure

Power-to-X

Content

On the contents:

This basic brochure provides an insight into the topic of explosion protection. The document helps planners, installers, and operators of systems in their day-to-day work, but is no substitute for the ongoing study of the relevant legal principles and standards. This brochure explains the physical basics surrounding how explosions form and the technical measures that can be taken to prevent them. Furthermore, the globally relevant legal bases and standards as well as the European directives and North American standards for electrical explosion protection are described.

Moreover, the document provides assistance to system operators when installing systems in potentially explosive areas. Here, the focus is on the design and installation of intrinsically safe circuits.

Further information on explosion protection:
Simply type the web code into the search field on our website.

i **Web code:** #2267

1 Technical and legal bases for explosion protection

The safety of people and production processes as well as a clean environment are important corporate goals worldwide. The prerequisite for achieving these goals is to be aware of how explosions occur wherever combustible materials, oxygen, and sources of ignition can come together, and how to avoid them.

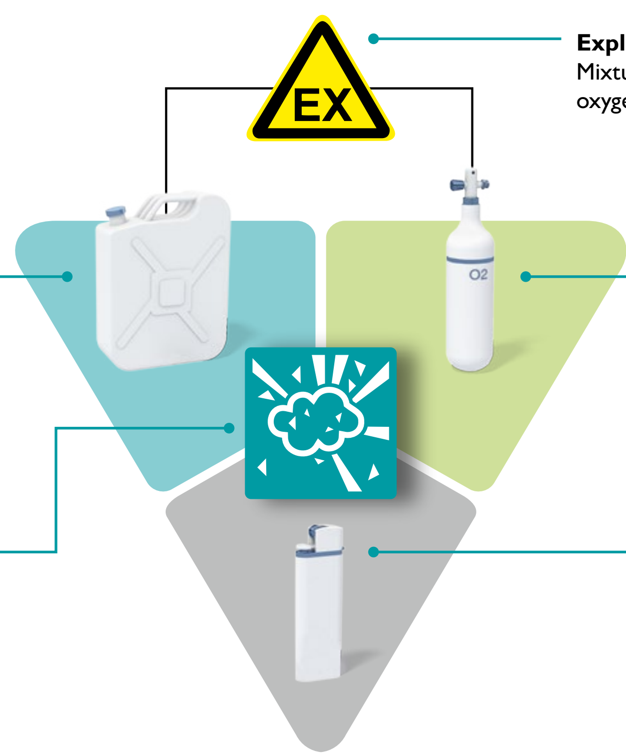
1.1 Formation and prevention of explosions

Combustion is an oxidation reaction in which energy is released. Whereas the energy during a fire is released slowly, when large amounts of energy are released suddenly it is referred to as an explosion. As the speed with which the combustion spreads increases, the process is referred to as fast combustion, then deflagration and, in extreme cases, detonation, in this order.

In the case of complete combustion, the damage caused increases significantly with the propagation velocity. Orders of magnitude of propagation:

- Fast combustion cm/s
- Deflagration m/s
- Detonation km/s

An explosion occurs when there is a combination of a combustible material, oxygen, and a source of ignition. If any one component is missing, no exothermic reaction occurs.



Explosive atmospheres
Mixture of combustible material and oxygen within the explosive limits

Combustible material
Combustible gases (mists, vapors) and combustible dusts

Oxygen
For example, oxygen contained in air

Explosion
Simultaneous presence of combustible material, oxygen, and source of ignition

Sources of ignition of electrical devices
For example, hot surfaces or energy/sparks

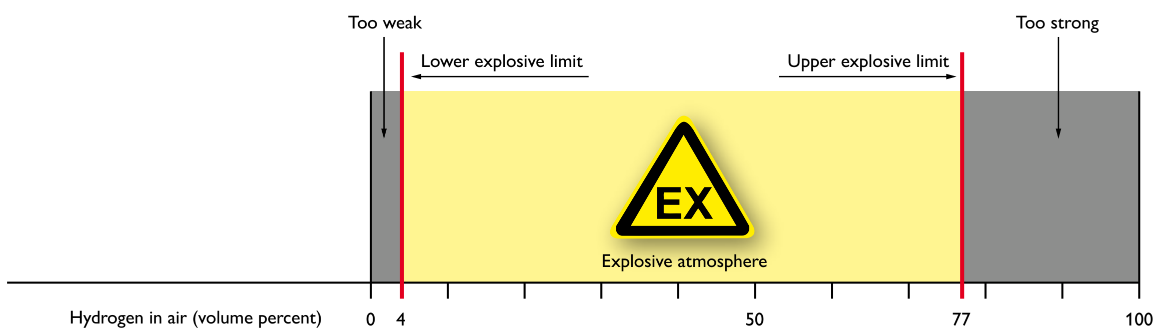
1.1.1 Upper and lower explosive limits

In the case of gases, the ratio of concentrations determines whether an explosion is possible. The mixture can only be ignited if the concentration of the material in air is between the lower explosive limit (LEL) and the upper explosive limit (UEL).

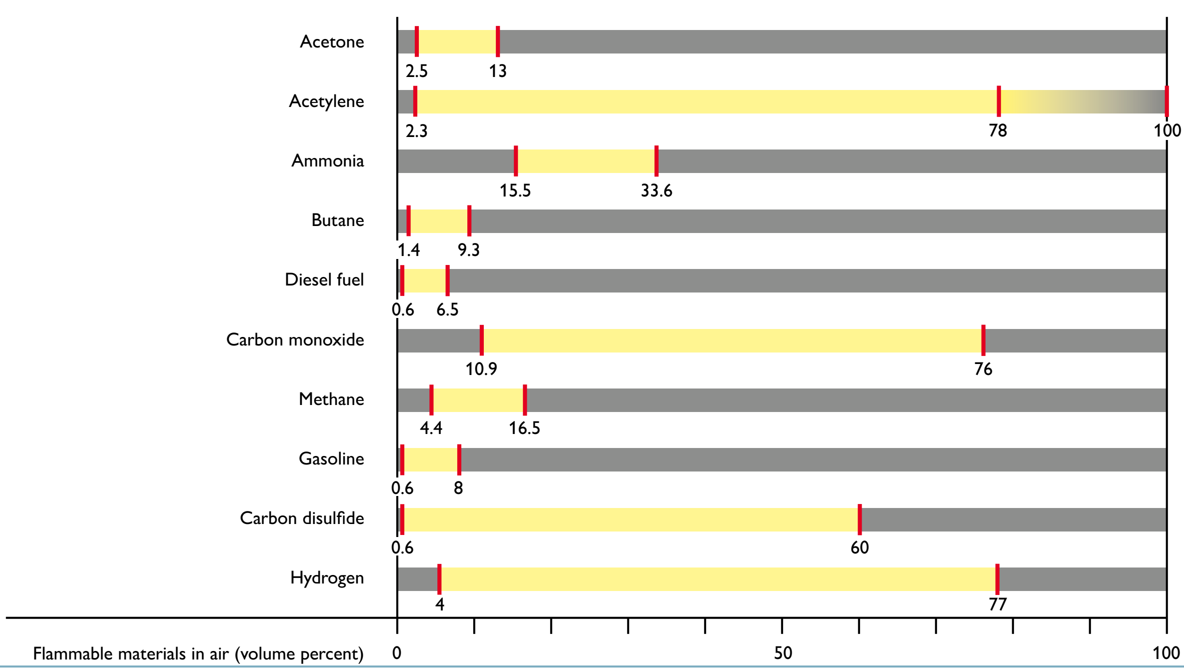
Some chemically non-resistant materials (e.g., acetylene, ethylene oxide) can also undergo exothermic reactions without oxygen through self-decomposition. The upper explosive limit (UEL) changes to 100 percent by volume. The explosion range of a material expands as the pressure and temperature rise.

Similar specifications as those defined for gases can also be made for dusts even though the explosive limits do not have the same meaning here. Clouds of dust are generally heterogeneous and the concentration within the same cloud fluctuates greatly. A lower flammability limit (of approximately 20 ... 60 g/m³) and an upper flammability limit (of approximately 2 ... 6 kg/m³) can be determined for dust. Due to different standards and the measuring procedures described therein, slightly different values may occur when determining the explosive limits. The limit values listed below are based on IEC/EN 60079-20.

Explosive limits of hydrogen



Examples of gases under normal pressure



1.1.2 Overview of effective sources of ignition

Source of ignition	Examples of causes
Sparks	Mechanically created sparks (e.g., caused by friction, impact, or abrasion processes), electric sparks. The operator is obligated to implement measures for explosion protection in a specified order.
Electric arcs	Short circuit, switching operations.
Hot surfaces	Heater, metal-cutting production, heating up during operation.
Flames and hot gases	Combustion reactions, flying sparks during welding.
Electrical systems	Opening/closing of contacts, loose contact. A protective extra-low voltage (U <50 V) is not an explosion protection measure. Low voltages can still generate sufficient energy to ignite a potentially explosive atmosphere.
Static electricity	Discharge of charged, separately arranged conductive parts – as with many plastics, for example.
Electrical compensating currents, cathodic corrosion protection	Reverse currents from generators, short circuit to exposed conductive part/ground fault in the event of errors, induction.
Electromagnetic waves in the range of 3 x 1,011 … 3 x 1,015 Hz	Laser beam for distance measurement, especially for focusing.
High frequency 104 … 3 x 1,012 Hz	Wireless signals, industrial high-frequency generators for heating, drying or cutting.
Lightning strike	Atmospheric weather disturbances.
Ionizing radiation	X-ray machine, radioactive material, absorption of energy leads to heating up.
Ultrasound	Absorption of energy in solid/liquid materials leads to heating up.
Adiabatic compression and shock waves	Sudden opening of valves.
Exothermic reactions	Chemical reaction leads to heating up.

1.1.3 Explosion protection measures

The operator is obligated to implement measures for explosion protection in a specified order. As a rule, priority must be given to measures to avoid potentially explosive atmospheres. It is therefore necessary to consider first whether and to what extent these measures can be applied in a meaningful way. If a satisfactory solution cannot be found, measures must be taken to avoid an ignition source. If this is not sufficient, design explosion protection measures are required – if necessary, even suitable combinations of the measures described. While primary explosion protection prevents the presence of the explosive atmosphere, with secondary explosion protection an explosion is safely prevented by avoiding effective ignition sources by design. Depending on the application, there are different types of protection with different protection principles for secondary explosion protection. There is also tertiary explosion protection. This involves design measures that reduce the consequences of an explosion to an acceptable level.

Order explosion protection measures

1. Primary explosion protection

Prevent formation
of hazardous explosive atmosphere.

- Avoid combustible materials (replacement technologies)
- Inertization (addition of nitrogen)
- Ventilation and air supply
- …

2. Secondary explosion protection

Prevent ignition
of hazardous explosive atmosphere.

- Electrical explosion protection

3. Constructive explosion protection

Limit impact
of an explosion to a safe level

- Pressure-resistant design
- Pressure relief and pressure compensation equipment (burst washers)

2 Directives, standards, and regulations

Special safety measures are required for the operation of systems and machines in areas with explosive atmospheres. The internationally applicable requirements are listed in the most important directives and standards for the global market.

2.1 Explosion protection in the European Union – ATEX directives

The ATEX Directive governs the harmonization of legal provisions in the member states for devices and protective systems in terms of ensuring correct use in potentially explosive areas. The term ATEX is derived from the French words “ATmosphère EXplosible”.

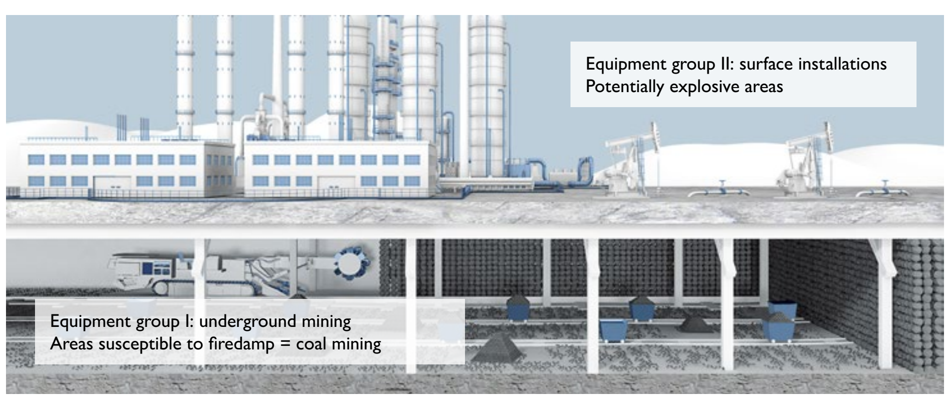
In order to address the issue of explosion protection, the European Union introduced ATEX Directive 2014/34/EU for manufacturers and Directive 1999/92/EC for operators. These directives were then translated into the national legislation of the different member states – in Germany, for example, into the manufacturer directive with the 11th Product Safety Ordinance (11th ProdSV), also called the Explosion Protection Product Ordinance (ExVO), and into the operator directive with the German Ordinance on Industrial Safety and Health (BetrSichV) and the Hazardous Materials Ordinance (GefStoffV).

Target group	Directive	Common designation
Manufacturers	2014/34/EU	ATEX 114
Operators	1999/92/EC	ATEX 137

Equipment group and category in accordance with ATEX Directive 2014/34/EU
In order to determine the appropriate procedure to be used for conformity assessment, the manufacturer must first decide which equipment group and category the product belongs to, based on its intended use (more information starting on page 9).

Equipment group I:
Equipment for use in underground mining and the connected surface installations which are endangered by firedamp (methane) or combustible dusts.

Equipment group II:
Equipment for use in all other areas which might be endangered by an explosive atmosphere.
Equipment categories are assigned to the equipment groups in Directive 2014/34/EU. Categories M1 and M2 are determined for equipment group I. Three categories – 1, 2, and 3 – are defined in equipment group II. The category is used to determine the connection with the zones in operator directive 1999/92/EC.



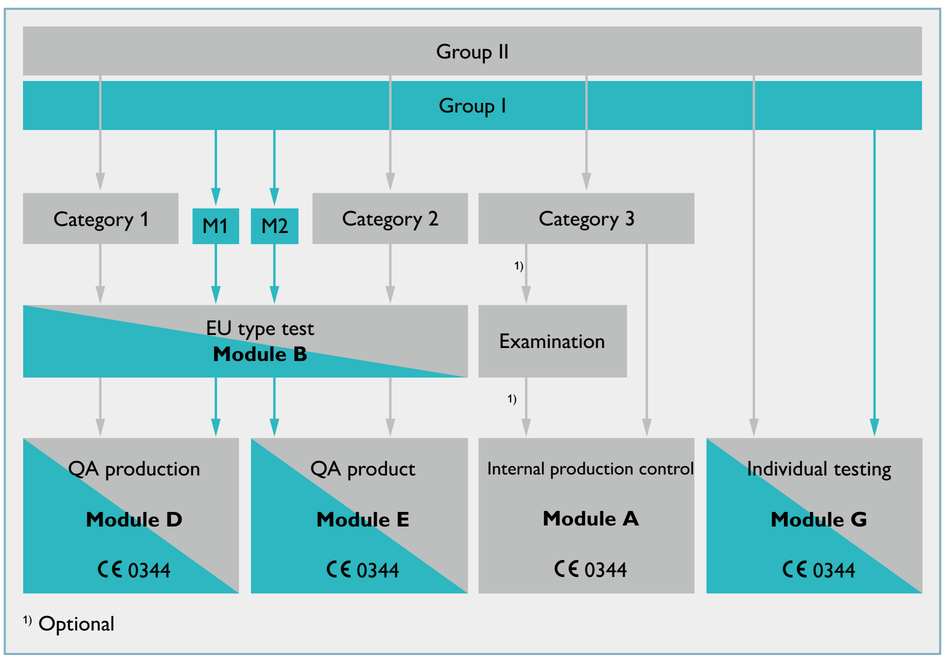
Requirements of equipment groups and categories

Equipment group	Equipment category	Degree of protection	Protection guarantee	Operating conditions
I	M1	Very high degree of safety	Two independent protective measures. Safe if two errors occur independently of one another.	For reasons of safety, it must be possible to continue operating a device even if the atmosphere is potentially explosive.
I	M2	High degree of safety	In normal operation, protective measures remain effective even under difficult conditions.	It must be possible to switch off these devices if a potentially explosive atmosphere occurs.
II	1	Very high	Two independent protective measures. Safe if two errors occur independently of one another.	Devices can still be used in zones 0, 1, 2 (G)[1], and 20, 21, 22 (D)[2] and continue to be operated.
II	2	High	Safe in normal operation and if common faults occur.	Devices can still be used in zones 1, 2 (G)[1], and 21, 22 (D)[2] and continue to be operated.
II	3	Normal	Safe in normal operation.	Devices can still be used in zones 2 (G)[1] and 22 (D)[2] and continue to be operated.

[1] (G) = gas [2] (D) = dust

Conformity assessment

Before a product can be placed on the market in the European Union, every manufacturer must conduct a conformity assessment procedure. There are several so-called Modules that the manufacturer can use for this depending on the group and category the product is classified into. A combination of Modules B and D is generally used for Category 1 and 2 electrical devices. The identification number of the notified body that is monitoring the production process is then added after the c marking, for example, c 0344. In the case of individual testing (Module G – unit verification), the identification number of the notified body that conducted the individual testing must be appended to the c marking. Module A (internal control of production) is used for Category 3 electrical devices. In this case, a Notified Body identification number may not be used.



Conformity assessment in accordance with Directive 2014/34/EU for electrical equipment

Notified body

Notified bodies (previously named bodies) are private testing institutions that have been named by the EU member states to conduct certain parts of a conformity assessment procedure.

For example, when Module B is being used in accordance with Directive 2014/34/EU, the notified body tests the technical design of the product and certifies it by issuing an EU Type test certificate stating that it has met the applicable requirements. An up-to-date overview of the notified bodies can be found in the Nando Information System of the European Commission.

Testing institute	Country	Identification
PTB	Germany	0102
DEKRA Testing and Certification GmbH	Germany	0158
TÜV Nord	Germany	0044
IBExU	Germany	0637
BAM	Germany	0589
INERIS	France	0080
LCIE	France	0081
LOM	Spain	0163
DEKRA Certification B.V.	Netherlands	0344
CESI	Italy	0722
UL DEMKO	Denmark	0539
NEMKO	Norway	0470

2.2 Explosion protection in North America – NEC and CEC

In the USA, the requirements governing installation of electrical devices are described in the National Electrical Code (NEC) NFPA 70, and in Canada in the Canadian Electrical Code (CEC) CSA C22.1. In addition to the requirements for standard use (ordinary locations), they also include requirements for use in potentially explosive areas (hazardous locations).

The fundamental component in this case is an approval, that is, a design-based assessment of the product performed by a recognized testing institute (National Recognized Testing Laboratory in the USA or a company accredited by the Standard Council of Canada in Canada).

Devices may be subdivided based on the Class/Division system, as it is known, or based on the Class/Zone system, which is in turn based on international standards. Since both systems are used, care must be taken when choosing devices to ensure that the approval matches the application. Devices that are approved under both systems spare the user the need for this consideration.

Well-known NRTLs include:

- Underwriter Laboratories Inc. (UL)
- CSA Group Testing and Certification Inc (CSA)
- FM Approvals LLC (FM)

National Electrical Code (NEC) in USA

Item	Content
500	General requirements for Divisions of Class I, II, and III
501	Requirements for Divisions of Class I
502	Requirements for Divisions of Class II
503	Requirements for Divisions of Class III
504	Requirements for Divisions of Class I, II, and III in relation to intrinsic safety (IS)
505	General and special requirements for zones 0, 1, and 2
506	General and special requirements for zones 20, 21, and 22

Canadian Electrical Code (CEC) in Canada

Item	Content
18-000	General requirements for Class I/zone and Class II and III/Divisions
18-090	Requirements for zone 0 of Class I
18-100	Requirements for zone 1 and 2 of Class II
18-200	Requirements for Divisions of Class II
18-300	Requirements for Divisions of Class III
Appendix J	General and special requirements for divisions of Class I

2.3 Worldwide explosion protection – IECEx

IECEx is an international method for certifying equipment that is used in potentially explosive areas. The aim of the IECEx schema is to harmonize national and international Ex standards. This simplifies the global trade in equipment for potentially explosive applications without compromising on the high safety level of the ATEX directive. The equipment certified in accordance with IECEx is recognized worldwide by the internationally uniform standards, tests, and test marks.
Based on existing IECEx approvals, national approvals such as CCC for China, INMETRO for Brazil or Kosha (KC) for Korea can be obtained more easily.

2.4 Standardization – electrical explosion protection for manufacturers

Manufacturers can use a range of standards when assessing their products during and after development.

The ATEX Directive 2014/34/EU stipulates compliance with basic safety and health requirements. This is achieved through the use of the harmonized standards published in the Official Journal of the European Union (EN standards), for example.

As already mentioned under 2.3, the IECEx standards published by the International Electrotechnical Commission (IEC) form the basis for almost all of the harmonized standards, as well as an ever-increasing number of the standards in use from various countries. The IEC 60079 series of standards deals with electrical explosion protection for gas and dust atmospheres worldwide. In addition, there are also national standards and standards specific to testing institutions, such as certain UL standards. Just as there are standards regarding gas explosion protection, there are also standards for dust explosion protection.

Standards for electrical equipment in areas with a danger of gas explosions

Type of protection	Symbol	NEC reference	CEC reference	Principle
General requirements				Basis for types of protection
Intrinsic safety	Ex AEx i IS	Article 505 Article 504	Section 18 Section J	Energy limitation
Increased safety	Ex e AEx e	Article 505	Section 18	Constructional measures through spacing and dimensioning
Non-hazardous to ignite	NI	Article 501	Section J	Constructional measures through spacing and energy limitation
Explosion-proof	XP	Article 501	Section J	Constructional measures through housing
Flameproof enclosure	Ex d AEx d	Article 505	Section 18	Constructional measures through housing
Molded encapsulation	Ex m AEx m	Article 505	Section 18	Exclusion of an explosive atmosphere
Liquid immersion	Ex o AEx o	Article 505	Section 18	Exclusion of an explosive atmosphere
Sand filling	Ex q AEx q	Article 505	Section 18	Exclusion of an explosive atmosphere
Pressurized enclosure	Ex p AEx p Type X, Y, Z	Article 505 Article 501	Section 18 Section J	Exclusion of an explosive atmosphere
Type of protection "n"	Ex n AEx n	Article 505	Section 18	Better industrial quality
Intrinsically safe systems	Ex i			Energy limitation in interconnected intrinsically safe circuits
Optical radiation range	Ex op AEx op	Article 505	Section 18	Limitation of radiation power

IS = Devices with intrinsically safe circuits NI = non-incendive equipment and non-incendive field circuits
XP = Explosion-proof type X, Y, Z = pressurized enclosure

Standards for electrical equipment in areas with a danger of dust explosions

Type of protection	Symbol	NEC reference	CEC reference	Principle
General requirements				Basis for types of protection
Protection provided by housing	Ex t AEx t DIP DT	Article 506 Article 502 Article 502	Section 18 Section J Section J	Protection through housing design
Intrinsic safety	Ex i AEx i IS	Article 505 Article 504	Section 18 Section J	Energy limitation
Pressurized enclosure	Ex p AEx p Type X, Y, Z	Article 505 Article 502	Section 18 Section J	Exclusion of an explosive atmosphere
Molded encapsulation	Ex m AEx m	Article 505	Section 18	Exclusion of an explosive atmosphere
Optical radiation range	Ex op AEx op			Limitation of radiation power
Non-hazardous to ignite	NI	Article 502	Section J	Energy limitation

DT = Dust-proof housing DIP = Dust explosion-protected IS = Devices with intrinsically safe circuits
NI = Non-incendiary equipment and non-incendiary type X, Y, Z = pressurized enclosure

EN standard	IEC standard	USA, Division (NEC 500)	USA, zone (NEC 505)	Canada, division	Canada, zone
EN IEC 60079-0	IEC 60079-0		UL 60079-0		CSA C22.2 No. 60079-0
EN 60079-11	IEC 6079-11	UL 913	UL 60079-11	CSA C22.2 No. 157	CSA C22.2 No. 60079-11
EN IEC 60079-7	IEC 60079-7		UL 60079-7		CSA C22.2 No. 60079-7
		UL 121201		CSA C22.2 No. 213	
		UL 1203		CSA C22.2 No. 30	
EN 60079-1	IEC 60079-1		UL 60079-1		CSA C22.2 No. 60079-1
EN 60079-18	IEC 60079-18		UL 60079-18		CSA C22.2 No. 60079-18
EN 60079-6	IEC 60079-6		UL 60079-6		CSA C22.2 No. 60079-6
EN 60079-5	IEC 60079-5		UL 60079-5		CSA C22.2 No. 60079-5
EN IEC 60079-2	IEC 60079-2	NFPA 496	UL 60079-2	NFPA 496	CSA C22.2 No. 60079-2
EN IEC 60079-15	IEC 60079-15		UL 60079-15		CSA C22.2 No. 60079-15
EN IEC 60079-25	IEC 60079-25				
EN 60079-28	IEC 60079-28		UL 60079-28		CSA C22.2 No. 60079-28

EN standard	IEC standard	USA, division	USA, zone	Canada, division	Canada, zone
EN IEC 60079-0	IEC 60079-0		UL 60079-0		CSA C22.2 No. 60079-0
EN 60079-31	IEC 60079-31	UL 1203 UL 121201	UL 60079-31	CSA C22.2 No. 25 CSA C22.2 No. 213	CSA C22.2 No. 60079-31
EN 60079-11	IEC 60079-11	UL 913	UL 60079-11	CSA C22.2 No. 157	CSA C22.2 No. 60079-11
EN IEC 60079-2	IEC 60079-2	NFPA 496	UL 60079-2	NFPA 496	CSA C22.2 No. 60079-2
EN 60079-18	IEC 60079-18		UL 60079-18		CSA C22.2 No. 60079-18
EN 60079-28	IEC 60079-28		UL 60079-28		CSA C22.2 No. 60079-28
		UL 121201		CSA C22.2 No. 213	

2.5 Standardization – mechanical explosion protection for manufacturers

ATEX Directive 2014/34/EU contains harmonized requirements for non-electrical devices, including use in areas with a danger of dust explosions. There are standards for non-electrical devices, just as there are for electrical devices.

Type of protection	Symbol	EN standard	IEC standard
Basic method and requirements		EN ISO 80079-36	ISO IEC 80079-36
Flameproof enclosure	d	EN 60079-1	IEC 60079-1
Pressurized enclosure	p	EN 60079-2	IEC 60079-2
Constructional safety	c	EN ISO 80079-37	ISO 80079-37
Control of ignition source	b	EN ISO 80079-37	ISO 80079-37
Liquid immersion	k	EN ISO 80079-37	ISO 80079-37

2.6 Standardization – explosion protection for system operators

Directive 1999/92/EC requires operators of process engineering systems to ensure that the systems are protected against explosion. The requirements to be met with regard to planning, installation, and operation are specified in the EN and IEC standards.

Designation	EN standard	IEC standard
Explosion protection **Part 1:** Basic concepts and methodology	EN 11271	
Explosive atmospheres **Part 10.1:** Classification of areas – explosive gas atmospheres **Part 10.2:** Classification of areas – explosive dust atmospheres	EN 60079-10-1 EN 60079-10-2	IEC 60079-10-1 IEC 60079-10-2
Potentially explosive areas **Part 14:** Configuration, selection, and installation of electrical systems	EN 60079-14	IEC 60079-14
Potentially explosive areas **Part 17:** Testing and maintenance of electrical systems	EN 60079-17	IEC 60079-17
Potentially explosive areas **Part 19:** Equipment repair, overhaul, and reclamation	EN 60079-19	IEC 60079-19

3 Classification of potentially explosive areas into zones

Potentially explosive areas are divided into zones in accordance with to ATEX and IECEx. In the USA, there is also the division concept (NEC 500) in addition to the zone concept (NEC 505). Zone classification is the responsibility of the plant operator.

3.1 Zone classification in accordance with ATEX and IECEx

The zone division is regulated in Europe via the ATEX Directive 1999/92/EC (Workplace Directive). Furthermore, there are standards for zone classification in IEC/EN°60079-10. The European Committee for Standardization (CEN) has also created standard EN 11271. EN 11271 contains basic information on explosion protection and provides support for both ATEX Directives (2014/34/EU and 1999/92/EC). In addition, there is country-specific assistance for zone classification, such as the explosion protection rules of the German Federal Employers' Association for Chemical Industry.

Explosive areas for gases and dusts are likewise classified into zones:

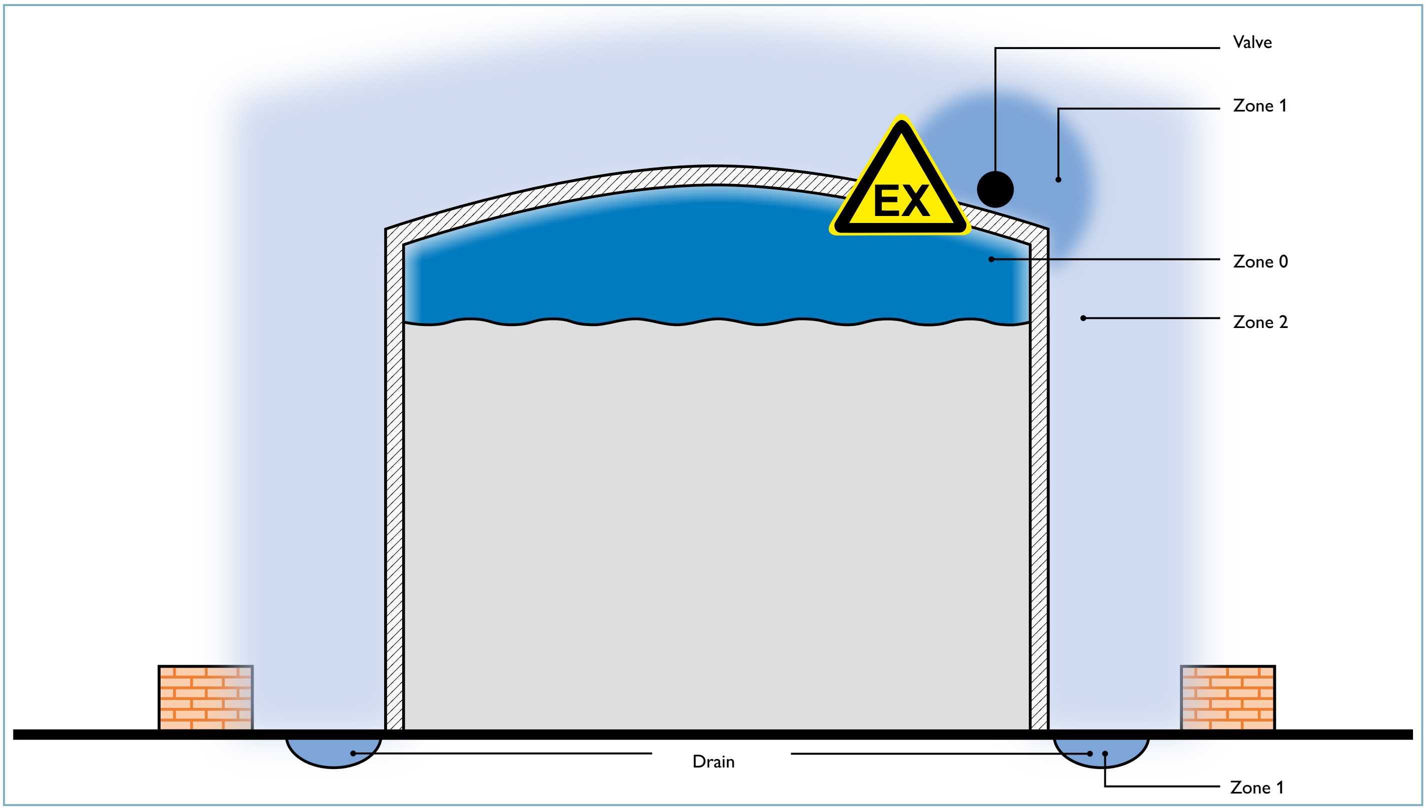
Zone classification for gases in accordance with ATEX Directive 1999/EC/92 and IEC/EN 60079-10-1

Zone classification	Type and duration of the danger
Zone 0	Area in which an explosive atmosphere consisting of a mixture of air and combustible materials in the form of gas, vapor, or mist is present **continuously** or **for long periods** or **frequently.**
Zone 1	Area in which an explosive atmosphere consisting of a mixture of air and combustible materials in the form of gas, vapor, or mist is likely to occur in normal operation **occasionally.**
Zone 2	Area in which an explosive atmosphere consisting of a mixture of air and combustible materials in the form of gas, vapor, or mist **is not likely to occur** in normal operation but, if it does occur, **will persist for a short period only.**

Zone classification for dusts in accordance with ATEX Directive 1999/EC/92 and IEC/EN 60079-10-2

Zone classification	Type and duration of the danger
Zone 20	Area in which an explosive atmosphere in the form of an airborne cloud of combustible dust is present **continuously** or for **long periods** or **frequently** present.
Zone 21	Area in which an explosive atmosphere in the form of an airborne cloud of combustible dust is **likely** to occur in normal operation occasionally.
Zone 22	Area in which an explosive atmosphere in the form of an airborne cloud of combustible dust **is not likely to occur in normal operation** but, **if it does occur, will persist for a short period only.**

Zone classification for gas using the example of a storage tank for flammable liquids



Zone 0
- Inside the tank above the combustible liquid

Zone 1
- Area (e.g., 2 m radius) around the inlet and outlet valve
- Sinks in which flammable gases that are heavier than air can accumulate

Zone 2
- Area around the tank up to the protective wall

3.2 Zone or division classification in accordance with NEC and CEC

In the National Electrical Code (NEC), explosive areas in the USA and in Europe are assigned according to their danger. In Canada, the procedure comparable and based on the Canadian Electrical Code (CEC).

However, for a long time, only a division of potentially explosive areas into two classes or divisions was common in the USA in accordance with Article 500 of the NEC.

It was only with Article 505 of the NEC from 1996 that the international classification of potentially explosive areas into three zones for gases/liquids and dusts was also introduced in the USA.

Both legal standards (Article 500 and Article 505) exist side by side.

As already mentioned, Article 500 of the NEC only recognizes two areas with regard to the frequency of occurrence, whereby a distinction is only made between the explosion hazard in normal operation (Division I) and in the event of malfunctions or defects (Division II). However, when defining potentially explosive areas, it relies on a different subdivision by focusing on the type of hazardous source (gas, liquid, dust, etc.) and the severity of the explosion hazard. The various areas (divisions) are therefore divided into further classes (class) and groups (groups).

Simplified assignment diagram for zones and division concepts

	Explosive area					
IEC/EN	Zone 0	Zone 1		Zone 2		
USA: NEC 505	Zone 0	Zone 1		Zone 2		
USA: NEC 500	**Division 1**			**Division 2**		
	Explosive material	Class	Group	Explosive material	Class	Group
	Gas/vapor or liquid	I	A, B, C, D	Gas/vapor or liquid	I	A, B, C, D
	Dust	II	E, F, G	Dust	II	F, G
	Fibers	III	—	Fibers	III	—

This simplified assignment scheme can only be regarded as a rough approximation of the possibilities. Any conversion must be verified on a case-by-case basis. This applies in particular to electrical equipment for Division 2, which can often only be used in zone 2 without additional testing and certification.

Divisional divisions into areas and groups in accordance with NEC 500

Area	**Groups (typical material)**
Class I (gases and vapors)	Group A (acetylene) Group B (hydrogen) Group C (ethylene) Group D (propane)
Class II (dusts)	Group E (metal dust) Group F (coal dust) Group G (grain dust)
Class III (fibers)	No subgroups

3.3 Overview of divisions and classes in accordance with NEC 500

Classification	Explosive atmospheres	Type of danger
Class I, Division 1	Gas, liquid, and vapor	Incendiary concentrations of inflammable gases, vapors or liquids may be present constantly or temporarily under normal operating conditions.
Class I, Division 2	Gas, liquid, and vapor	Incendiary concentrations of inflammable gases, vapors or liquids do not usually occur under normal operating conditions.
Class II, Division 1	Dust	Incendiary concentrations of combustible dust may be present constantly or temporarily under normal operating conditions.
Class II, Division 2	Dust	Incendiary concentrations of combustible dust do not usually occur under normal operating conditions.
Class III, Division 1	Fibers	Areas in which readily flammable fibers are processed or transported.
Class III, Division 2	Fibers	Areas in which readily flammable fibers are stored or transported.

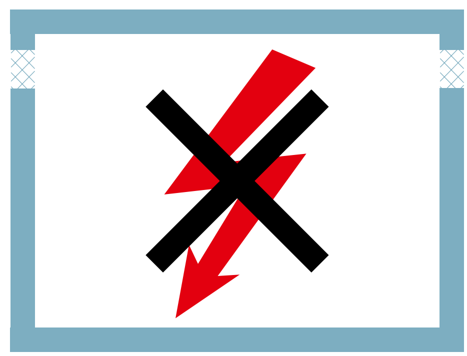
4 Types of protection

Depending on the application, there are different types of protection with different protection principles for secondary explosion protection. What they all have in common is that the ignition of an explosive atmosphere is avoided.

4.1 Overview of essential types of protection

4.1.1 Increased safety Ex e

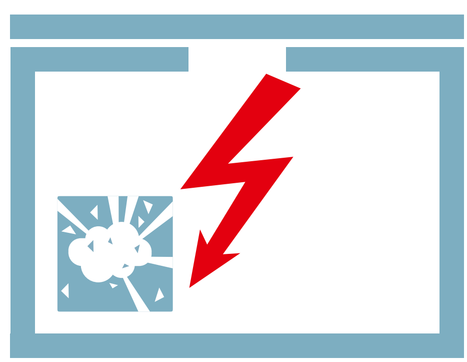
In increased safety protection, voltages up to 11 kV can be brought into the potentially explosive area. Increased safety is particularly suitable for supplying motors, lamps, and transformers.
The protection principle is based on constructional measures. Air clearances and creepage distances are determined for the live parts and divided into voltage levels. This prevents electrical sparks.
In addition, IP54 degree of protection (EN 60529) must be satisfied at the very least. Limiting the surface temperature ensures that the explosive atmosphere cannot be ignited at any point, not even inside the housing, during operation. The housing does not rule out the ingress of gases. For increased safety, the IP degree of protection can be reduced to IP20, for example, if additional protective measures are taken. Some of these must be taken into consideration during installation.



4.1.2 Flameproof enclosure Ex d

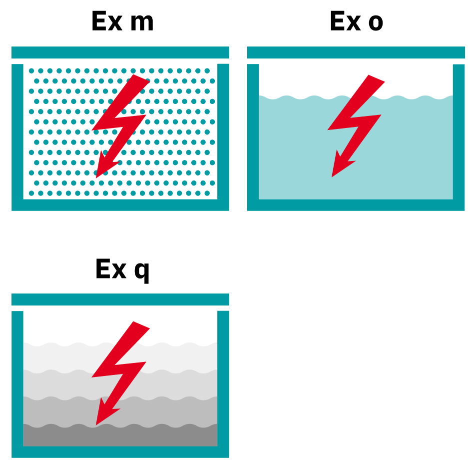
In flameproof enclosure protection, an explosion is prevented from spreading by the housing design. An explosion that occurs inside is not able to ignite the explosive atmosphere surrounding the housing. This leads to very robust housings. The housings have covers and entry points, for example, for cables and lines. The maximum permitted gap that is present is dimensioned in such a way that it prevents the explosion from spreading from inside the housing to the surrounding explosive atmosphere.

Altering cable and line entries in type of protection Ex d, for example, by removing rust with a wire brush, is not permitted. Doing this could change the gap, thus destroying the protection principle. The manufacturer's specifications must be strictly observed.



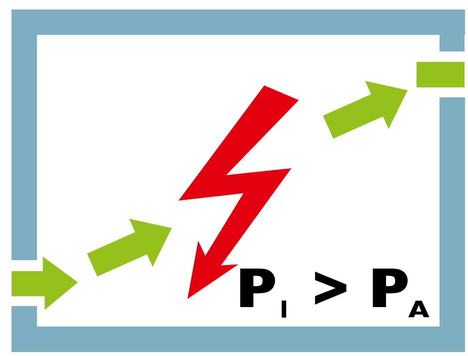
4.1.3 Molded encapsulation, sand filling, or oil immersion Ex m, Ex q, Ex o

The principle of molded encapsulation, sand filling, and oil immersion protection types of protection is to surround possible sources of ignition in an item of electrical equipment with the medium of a molding compound, sand, or oil. This prevents the explosive atmosphere from igniting. Voltages from 10 … 11 kV can also be used in these types of protection.



4.1.4 Pressurized enclosure Ex p

Pressurized enclosure protection describes methods that use overpressure to prevent an explosive atmosphere from entering into housings or the control room. The ambient pressure surrounding the housing is always lower than the pressure inside. Three forms of pressurized enclosure are possible (see table). In the case of static overpressure, the housing must be hermetically sealed. There is no loss of pressure. More common, however, are methods in which the overpressure is maintained by compensating the leakage losses or by continuous purging. The overpressure is usually created by simple compressed air. Ex p protection requires a monitoring unit that reliably switches off the electrical equipment inside the housing as soon as sufficient overpressure is no longer present. The monitoring unit must be designed in a different type of protection so that it can also be operated without overpressure. Items of equipment can be operated inside without taking explosion protection into account. The surface temperature of the items of equipment must not ignite the penetrating potentially explosive atmosphere once the overpressure has dropped. If operational conditions dictate that a device or component inside the housing must not be switched off, it must be protected against explosion with a different type of protection.

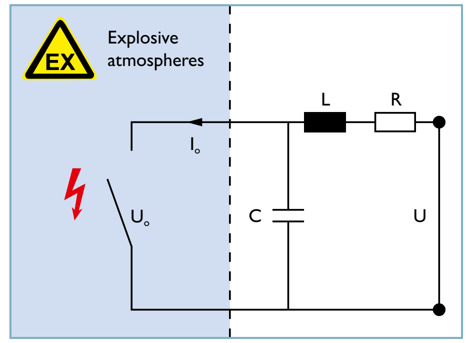


Possibilities of pressurized enclosure

Pressurized enclosure	Static	Compensation of the leakage losses	Continuous purging
Compressed air	Without correction	Compensation of the leakage losses	Continuous correction
Operating states	---	Pre-purging phase: The housing is purged and any explosive atmosphere that is present is removed from the housing. Operating phase: The overpressure in the housing is monitored. If it decreases, the electrical equipment inside the housing is switched off.	

4.1.5 Ex i intrinsic safety protection

Intrinsic safety protection, as opposed to other types of protection (such as increased safety), refers not only to individual items of equipment, but to the entire circuit. A circuit is described as intrinsically safe if the current and voltage are limited to such an extent that no spark or thermal effect can cause a potentially explosive atmosphere to ignite. The voltage is limited in order to keep the energy of the spark below the ignition energy of the surrounding gas. The thermal effect, that is, excessively hot surfaces, is prevented by limiting the current. This is also true of the sensors connected to the intrinsically safe circuits. Energy may also be stored in the form of capacitances or inductances within the intrinsically safe circuit. This must also be taken into consideration when examining the intrinsically safe circuit.



4.1.6 Ex n protection

The n type of protection can be described as an improved industrial quality that is designed for normal operation. An additional error consideration is not carried out and therefore the type of protection n is only suitable for use in zone 2 or zone 22. This can only be used in device group II (ATEX) or in groups II and III (IECEx).

The manufacturer specifies the technical data for normal operation. In the case of type of protection n, a distinction is made between five different versions, which can be derived in part from the familiar types of protection: increased safety, intrinsic safety, flameproof enclosure, pressurized enclosure, and molded encapsulation.

The type of protection n includes the types of protection nA, nC, and nR. Since the IEC 60079-15:2005 IEC 60079-15:2010 type of protection, the nZ has been included in the protection level pzc in the IEC 60079-2:2014 type of protection. nL has been included in the protection level ic in the standard IEC 60079-11:2006. nA type of protection is no longer included in the current edition IEC/EN 60079-15:2017. It has already been adopted into IEC 60079-7:2015 as safety level “ec”.

Subdivision of type of protection n in accordance with IEC/EN 60079

Abbreviation	Significance	Comparable with ...	Method	Subdivision of the groups in accordance with IECEx
A	Non-sparking	Ex e	Occurrence of electric arcs, sparks, or hot surfaces is minimized.	As of IEC 60079-0:2007, subdivided into IIA, IIB, IIC
C	Sparking equipment	To some extent, Ex d and Ex m	Enclosed switching device, nonflammable components, hermetically sealed, sealed, or encapsulated installations.	IIA, IIB, IIC, and IEC 60079-0:2007
R	Restricted breathing housings	---	Ingress of explosive gases is limited.	As of IEC 60079-0:2007, subdivided into IIA, IIB, IIC

4.2 Protection types and their applications

Types of protection for electrical equipment in areas with a danger of gas explosions

Type of protection		Protection principle	EN/IEC	Zone	Application
da d, db dc	Flameproof enclosure	Prevention of explosion spreading	EN 60079-1 IEC 60079-1	0 1 2	Switching, control, and signaling devices, controllers, motors, power electronics
px py pz	Pressurized enclosure	Exclusion of an explosive atmosphere	EN 60079-2 IEC 60079-2	1 2	Control cabinets, motors, measuring and analysis devices, computers
q	Sand filling	Prevent spark propagation and increased temperatures	EN 60079-5 IEC 60079-5	1 2	Transformers, relays, capacitors
ob oc	Oil immersion	Exclusion of an explosive atmosphere	EN 60079-6 IEC 60079-6	1 2	Transformers, relays, startup controls, switching devices
eb ec	Increased safety	Prevent spark propagation and increased temperatures	EN 60079-7 IEC 60079-7	1 2	Branch and connection boxes, housing, motors, terminal blocks, electrical devices
ia ib ic	Intrinsic safety	Energy limitation	EN 60079-11 IEC 60079-11	0 1 2	Measurement and control technology, sensors, actuators, instrumentation
	Intrinsically safe fieldbus systems (FISCO)		EN 60079-25 IEC 60079-25	0 1 2	
nA	Non-sparking equipment	Prevent sparks, comparable with Ex ec	EN 60079-15 IEC 60079-15	2	Electrical equipment for normal industrial applications
nC	Sparking equipment	Sealed or hermetically sealed equipment	EN 60079-15 IEC 60079-15	2	Electrical equipment for normal industrial applications
nR	Restricted breathing housing	Protection provided by housing	EN 60079-15 IEC 60079-15	2	Electrical equipment for normal industrial applications
ma mb mc	Molded encapsulation	Exclusion of an explosive atmosphere	EN 60079-18 IEC 60079-18	0 1 2	Coils of relays and motors, electronics, solenoid valves, connection systems
op	op is – inherently safe optical radiation op pr – protected optical radiation op sh – optical systems with interlock	Limiting or preventing the transmission of energy from optical radiation	EN 60079-28 IEC 60079-28	0 or 1 or 2 1 or 2 0 or 1 or 2	Optoelectronic devices

Electrical equipment in areas with a danger of dust explosions

Type of protection		Protection principle	EN/IEC	Zone	Application
ta tb tc	Protection provided by housing	Exclusion of an explosive atmosphere	EN 60079-31 IEC 60079-31	20 21 22	Switching, command, and signaling devices, lamps, branch and connection boxes, housings
pxb pyb pzc	Pressurized enclosure	Exclusion of an explosive atmosphere	EN 60079-2 IEC 60079-2	21 21 22	Control cabinets, motors, measuring and analysis devices
ia ib ic	Intrinsic safety	Energy limitation	EN 60079-11 IEC 60079-11	20 21 22	Measurement and control technology, sensors, actuators, instrumentation
ma mb mc	Molded encapsulation	Exclusion of an explosive atmosphere	EN 60079-18 IEC 60079-18	20 21 22	Coils and relays of motors, electronics, and connection systems

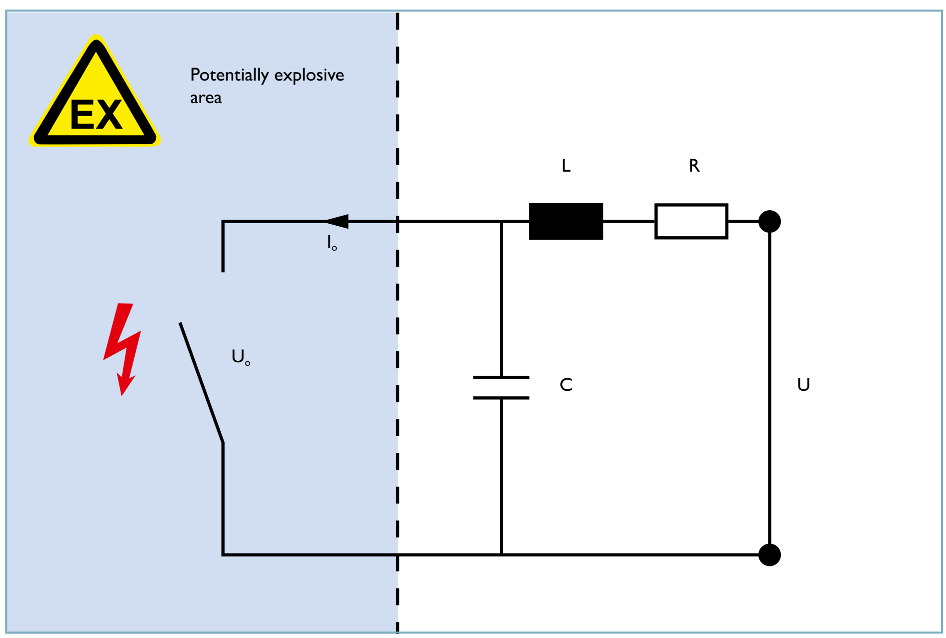
4.3 Intrinsic safety protection

4.3.1 Principle

Intrinsic safety (Ex i) type of protection has established itself worldwide in the field of measurement and control technology in systems with potentially explosive areas.
Intrinsically safe circuits are generally composed of the following elements:

- Intrinsically safe equipment, that is., a load installed in the Ex area, such as an Ex i temperature transmitter
- associated equipment, which involves a source in the non-Ex area (Ex i isolator)
- Connecting cable between intrinsically safe and associated equipment

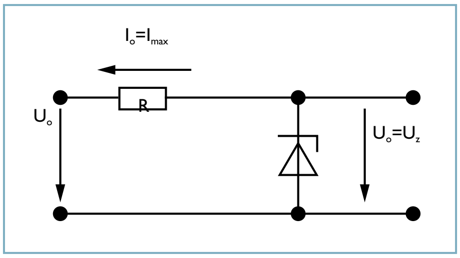
The protection principle behind the Ex bi type of protection is based on limiting the energy that is conducted to the potentially explosive area and is stored there. This means that the energy from any potential spark must always be less than the minimum ignition energy of the surrounding potentially explosive atmosphere. As opposed to all the other types of protection, Ex i refers not only to a single item of equipment but also to the entire intrinsically safe circuit, in accordance with IEC/EN 60079-11.



Basic intrinsically safe circuit diagram

The voltage is limited in order to keep the energy of the spark below the ignition energy of the surrounding gas. The thermal effect, that is, excessively hot surfaces, is prevented by limiting the current.

Voltage and current limitation



Basic circuit diagram for limiting voltage and current

The Zener diode becomes conductive at a defined voltage level. This limits the voltage U_o in the potentially explosive area. A resistor connected in series limits the maximum current I_o.

$$I_{max} = I_O = \frac{U_O}{R}$$

When limiting voltage and current, the following applies for the maximum power:

$$P_O = \frac{U_O^2}{4R}$$

The maximum permissible values are determined by the ignition limit curves specified in standard IEC/EN 60079-11. The ignition limit curves were determined using a spark tester, as described in Appendix B of IEC/EN 60079-11.

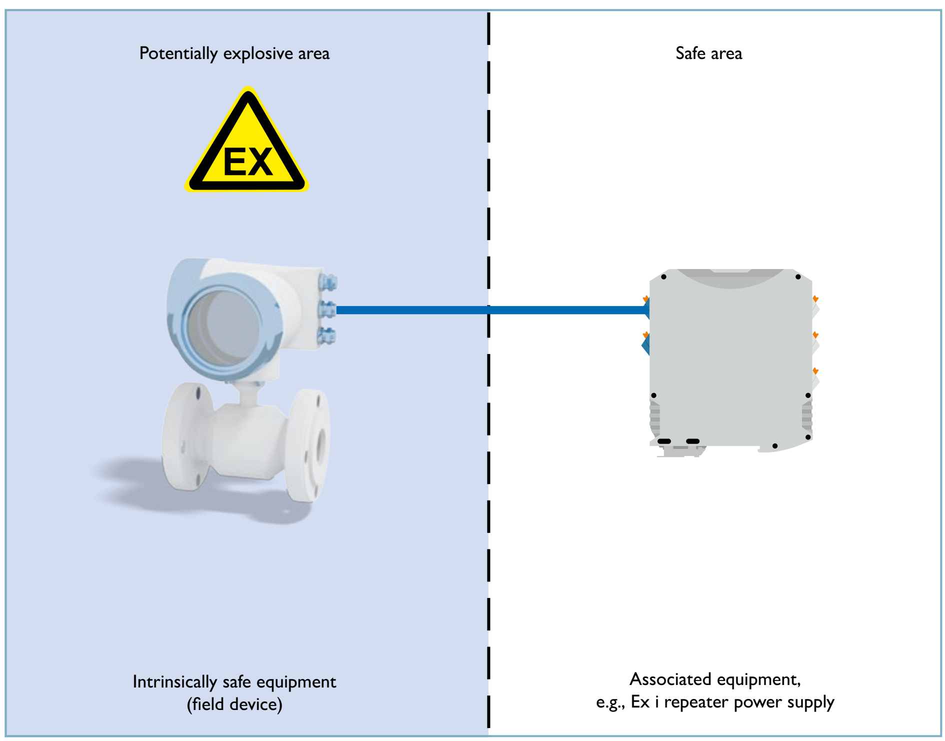
The ignition limit curves contain specifications for gas groups I and II as well as dust group III. Group II (gases) is further subdivided into IIA, IIB, and IIC, depending on the ignition energy. Group III (dusts) is divided accordingly into IIIA, IIIB, and IIIC.

Ignition energies of typical gases

Group	Typical gas	Ignition energy/µJ
I	Methane	280
IIA	Propane	>180
IIB	Ethylene	60 … 180
IIC	Hydrogen	<60

4.3.2 Intrinsically safe circuit

An intrinsically safe circuit consists of at least one item of intrinsically safe equipment and one item of associated equipment and connecting cables. The circuits of the electrical equipment satisfy the requirements of intrinsic safety. Intrinsically safe equipment may only be connected to non-intrinsically safe circuits via associated equipment. Associated equipment has both intrinsically safe circuits and non-intrinsically safe circuits. The circuits are isolated using Zener barriers or electrical isolators. Intrinsically safe equipment and intrinsically safe parts of associated equipment are classed in accordance with IEC/EN 60079-11 in safety levels ia, ib, and ic.



Example of an intrinsically safe circuit

4.3.3 Safety level in accordance with IEC/EN 60079-11

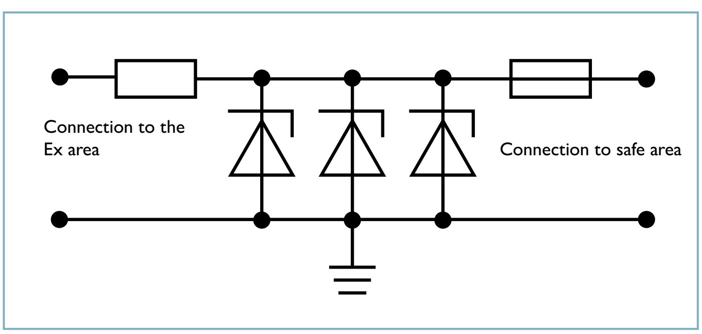
Safety level ia, ib or ic defines whether protection is maintained with two faults or one fault in the protective circuit, or whether no protection is provided in the event of a fault. Intrinsic safety is based on fault monitoring in order to rule out an explosion hazard. This does not, however, provide any conclusions as to operational safety. This means that a total functional failure of the equipment may be permissible from the point of view of explosion protection.

Electrical equipment can be used right up to zone 0 in accordance with the safety level. Associated equipment is installed in the safe area. Only the intrinsically safe circuits are routed into the potentially explosive area in accordance with the safety level. Associated equipment can always be designed with a different type of protection in order for it to be installed in zone 2 or perhaps even in zone 1.

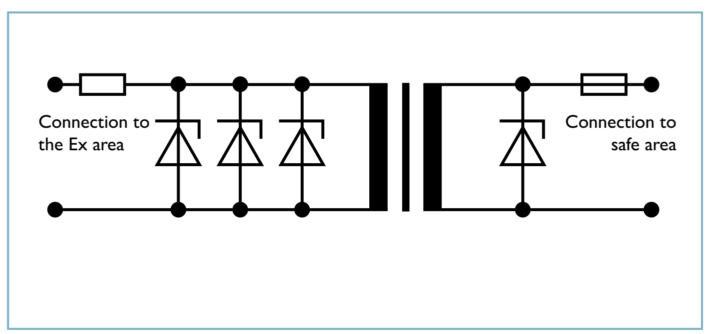
Safety level	Fault monitoring	Permissible zones
ia	Under normal operating conditions, not able to cause ignition if any combination of two faults occurs.	0, 1, 2
ib	Under normal operating conditions, not able to cause ignition if one fault occurs.	1, 2
ic	Under normal operating conditions, device is not able to cause ignition.	2

4.3.4 Associated equipment with or without electrical isolation

For intrinsically safe circuits in zone 0, the standard IEC/EN 60079-14 Section 12.3 recommends the preferential use of protection level “ia” in conjunction with electrical isolation.



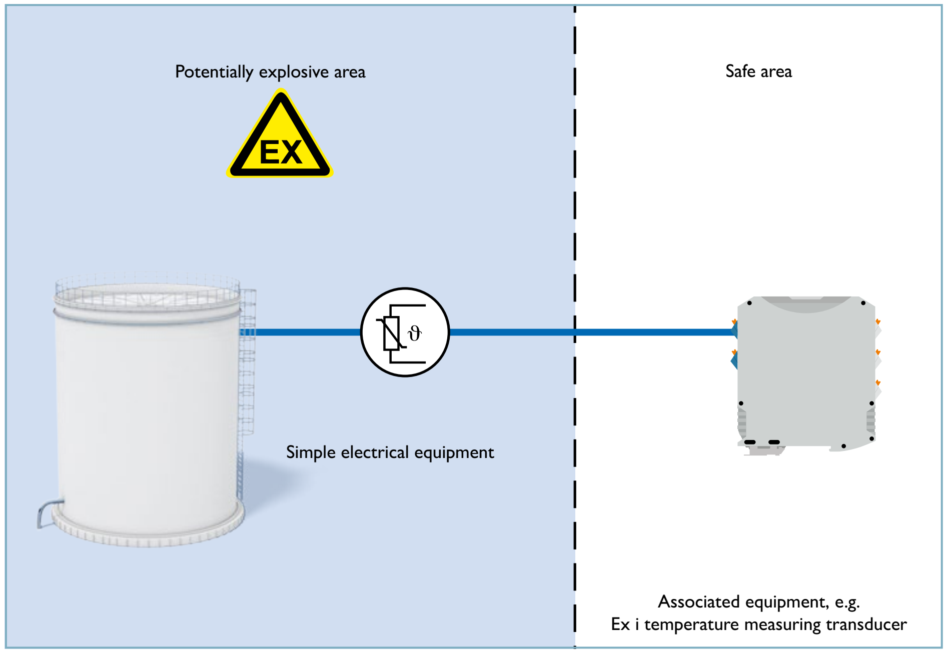
Without electrical isolation: Ex i Zener barrier



With electrical isolation: Ex i signal conditioner

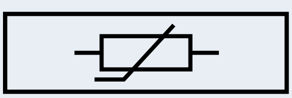
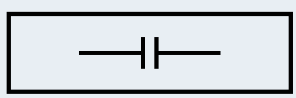
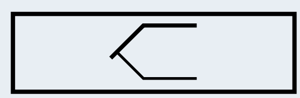
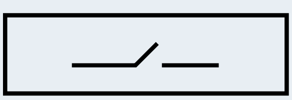
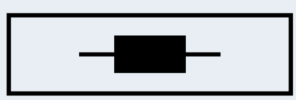
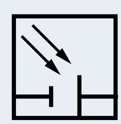
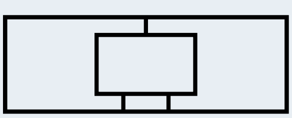
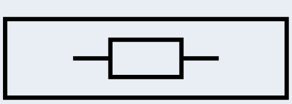
4.3.5 Simple electrical equipment

Simple electrical equipment does not require approval; however, it must be assigned to a temperature class and conform with any other applicable requirements of IEC/EN 60079-11. The maximum temperature can be calculated from power P_o of the associated equipment and the temperature class can then be determined. The characteristics of the energy storage must be specified precisely and must be taken into account when determining the overall safety of the system.



Example of an intrinsically safe circuit with simple electrical equipment

Overview of simple electrical equipment

Passive components	Energy storage	Energy sources*
 Pt 100	 Capacitors	 Thermocouples
 Switches	 Coils	 Photocells
 Distributor boxes		
 Resistors		*Requirement U ≤ 1.5 V I ≤ 100 mA P ≤ 25 mW

5 Selecting devices

The following section focuses on secondary explosion protection. When selecting devices, according to the types of protection, the user must analyze the type of danger and the duration and frequency of the danger. The type of danger is determined by examining the ignition source based on the ignition temperature and ignition energy. In the case of the duration and frequency of the danger, the relationship between zone classification and the equipment category and equipment protection level is established.

5.1 General requirements

Equipment classification by directive
The ATEX Directive requires that equipment be classified into groups and categories. Equipment group I includes underground and surface operations in mining. Equipment group II includes all other areas, such as the chemical industry, oil and gas processing, potentially explosive dusts in mills and silos, etc. The order they are arranged in is historical. Equipment categories 1 to 3 are a yardstick for how fail-safe the equipment is and are used to determine which of the different hazard zones of the potentially gas-explosive area it can be used in.

Equipment classification by standard
Since 2009, the IEC/EN 60079 series of standards has included an additional classification in accordance with gas groups (II) and dust groups (III) for surface use. However, the designation of gas groups from IIA to IIC and dust groups from IIIA to IIIC should not be confused with the ATEX Directive equipment groups, because the ATEX directives are differentiated solely by underground mining (I) and surface installations (II).

Areas	**Equipment group in accordance with Directive 2014/34/EU**	**IEC/EN 60079-0:2018**	
Mines susceptible to firedamp	Group I	Group I	
Areas with a danger of gas explosions	Group II	Group II	IIA IIB IIC
Areas with a danger of dust explosions	Group II	Group III*	IIIA IIIB IIIC

5.2 Type of hazard – source of ignition source consideration

When considering the ignition source, potential sources of ignition are considered according to the ignition energy and surface temperature:

Sparks/energy
Ignition of the explosive atmosphere is prevented if the ignition energy of the equipment is lower than the minimum ignition energy of the surrounding substances (see 5.2.1 Groups).

Hot surfaces
The explosive atmosphere can be prevented from igniting if the surface temperature of the equipment is lower than the ignition temperature of the surrounding gas (see 5.2.2 Temperature classes).

5.2.1 Groups for gases and dusts in accordance with the standard

Devices for use in Group II (gases) and III (dust) potentially explosive atmospheres are divided into groups (IIA, IIB, IIC, and IIIA, IIIB, IIIC), which indicate the maximum ignition energy of the device.

A device may only be used if the maximum ignition energy of the device is lower than the minimum ignition energy of the substance (gas or dust mixture). A device with IIC marking may be used for all gases and a device with IIIC marking may be used for all dusts.

Gases are more explosive than dusts: for example, devices with IIB are suitable for IIIC.

The division into group II in accordance with A, B, C is particularly important for the types of protection, flameproof enclosure (Ex d) and intrinsic safety (Ex i). For flameproof enclosure, it is based on the experimentally determined limit gap width (MWG), which reduces the transmission of the energy of an explosion inside to the explosive atmosphere surrounding the housing so that it is below the minimum ignition energy of the material. For intrinsic safety, the minimum ignition current ratio is decisive, which results in the maximum ignition energy of the Ex i circuit and which must be below the minimum ignition energy of the respective gases.

The following table provides an overview of the groups, the required ignition energy, and the resulting hazardousness of the substances as well as typical material examples.

Group	Required ignition energy	Danger from substances	Examples of substances
IIA	+++	+	Acetone, ethane, ammonia, carbon monoxide. Propane, butane, gasoline, diesel fuel, acetaldehyde
IIB	++	++	Methane, ethylene, ethyl ether, ethyl alcohol, hydrogen sulfide
IIC	+	+++	Hydrogen, acetylene, carbon disulfide
IIIA	+++	+	Combustible flyings, e.g., cotton fibers
IIIB	++	++	Non-conductive dust, e.g., flour, wood
IIIC	+	+++	Conductive dust, e.g., aluminum dust

5.2.2 Temperature classes/limits for gases and dusts by standard

Temperatures for group I (pit mines/mine susceptible to weather)
The maximum permissible surface temperature of the equipment depends on the type of coal dust deposit.

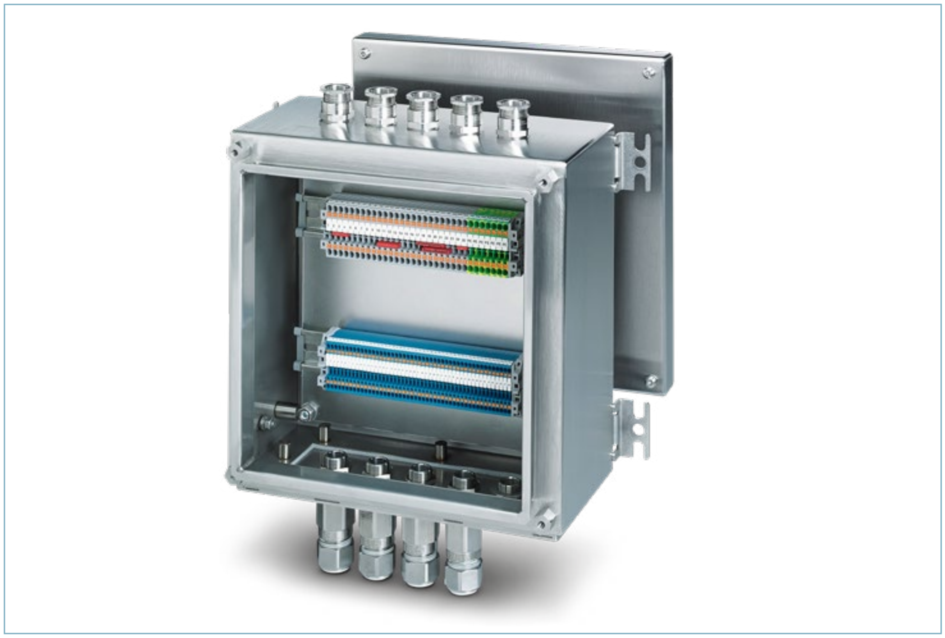
Group I	Temperature	Conditions
Mines susceptible to firedamp	150°C	With deposits of coal dust on the equipment
	450°C	Without deposits of coal dust on the equipment

Temperature classes for group II (gases)
The explosive atmosphere can be prevented from igniting if the surface temperature of the equipment is lower than the ignition temperature of the surrounding gas. The surface temperature is valid for all parts of an item of electrical equipment that can come into contact with the explosive material. The majority of gases can be assigned to temperature classes T1 to T3.

Temperature classes group II in accordance with IEC/EN 60079 and NEC 500

Temperature classes in accordance with IEC/EN 60079	Temperature classes in accordance with UL 913/ ISA 12.12.01 or NEC 500	Max. surface temperature of the equipment in °C	Ignition temperature range of the gas in °C	Examples
T1	T1	>300 … ≤450	>450	Carbon monoxide, methane, hydrogen
T2	T2	>200 … ≤300	> 300 … ≤450	Acetylene, butane, ethylene
	T2A	>260 … ≤280		
	T2B	>230 … ≤260		
	T2C	>215 … ≤230		
	T2D	>200 … ≤215		
T3	T3	>135 … ≤200	>200 … ≤300	Gasoline, hydrogen sulfide, cyclohexane
	T3A	>165 … ≤180		
	T3B	>160 … ≤165		
	T3C	>135 … ≤160		
T4	T4	>100 … ≤135	>135 … ≤200	Acetaldehyde, diethyl ether (no other substances)
	T4C	>100 … ≤120		
T5	T5	>85 … ≤100	>100 … ≤135	No substances
T6	T6	≤85	>85 … ≤100	Carbon disulfide

Example
The plan is to equip a housing with degree of protection IP54 (Ex eb IIC Gb) with approved terminal blocks and then comply with temperature class T6 in a potentially gas-explosive area. Since the gas can penetrate the housing, the maximum permissible temperature for T6 must not be exceeded either on the outside of the housing or inside at the terminals.


Terminal housing for a zone 1 area with a danger of gas explosions

Temperature limits for dust
For areas with a danger of dust explosions, the maximum surface temperature is not specified in temperature classes, but as a temperature limit with a specified temperature value (°C). The maximum surface temperature of the equipment must not exceed the ignition temperature of a layer of dust or a cloud of combustible dust.

This is because:
T_{Amax} = 2/3 $T_{Sparkling}$
and
T_{Amax} = 2/3 $T_{Glomerate}$ – 75°C
(up to 5 mm dust layer)

T_{Amax} = The maximum surface temperature of the equipment
$T_{Sparkling}$ = Ignition temperature of the dust layer
$T_{Glomerate}$ = Glow temperature of the dust layer

The maximum surface temperature of the equipment is the lowest of the two temperatures T_{Amax}. Further information can be found in the IEC/EN 60079-14 standard, for example.

5.3 Duration and frequency of danger

This section covers the relationship between zone classification as well as the equipment category and equipment protection level:

Zone classification
Both gas and dust-explosive areas are divided into three Ex zones. They differ in the duration and frequency of the hazard. The zone classification has already been described in detail in Section three.

Equipment category and equipment protection level
The equipment category or the equipment protection level indicates the safety of the device with regard to explosion protection.

5.3.1 Relationship between zones and equipment categories/equipment protection level

Equipment categories and equipment protection levels describe the safety level and the protection level of devices. Which devices are suitable for which zone is shown in ATEX Directive 2014/34/EU via the equipment category (categories 1, 2, 3). In standard IEC/EN 60079-0, the applicability of the devices for the respective zones is described via the equipment protection level (EPL: a, b, c). For both the equipment category marking and the equipment protection level, the G stands for “gas” and the D for “dust”. For example, in gas applications, a device marked 1G and Ga, that is, with a very high level of safety and protection, is suitable for the most hazardous zone 0 and therefore also for all other gas zones. Structurally, this device is designed to still be safe in the event of two independent faults.

Zone classification Directive 1999/92/EC	Safety level or protection level	Equipment category ATEX Directive 2014/34/EU	Equipment protection level (EPL) Standard IEC/EN 60079-0
Gas zones			
Zone 0	Very high – the device is still safe in the event of two independent faults	1G	Ga
Zone 1	High – in the event of an independent error, the device is still safe	2G	Gb
Zone 2	Normal – not failsafe	3G	Gc
Dust zones			
Zone 20	Very high – the device is still safe in the event of two independent faults	1D	Da
Zone 21	High – in the event of an independent error, the device is still safe	2D	Db
Zone 22	Normal – not failsafe	3D	Dc

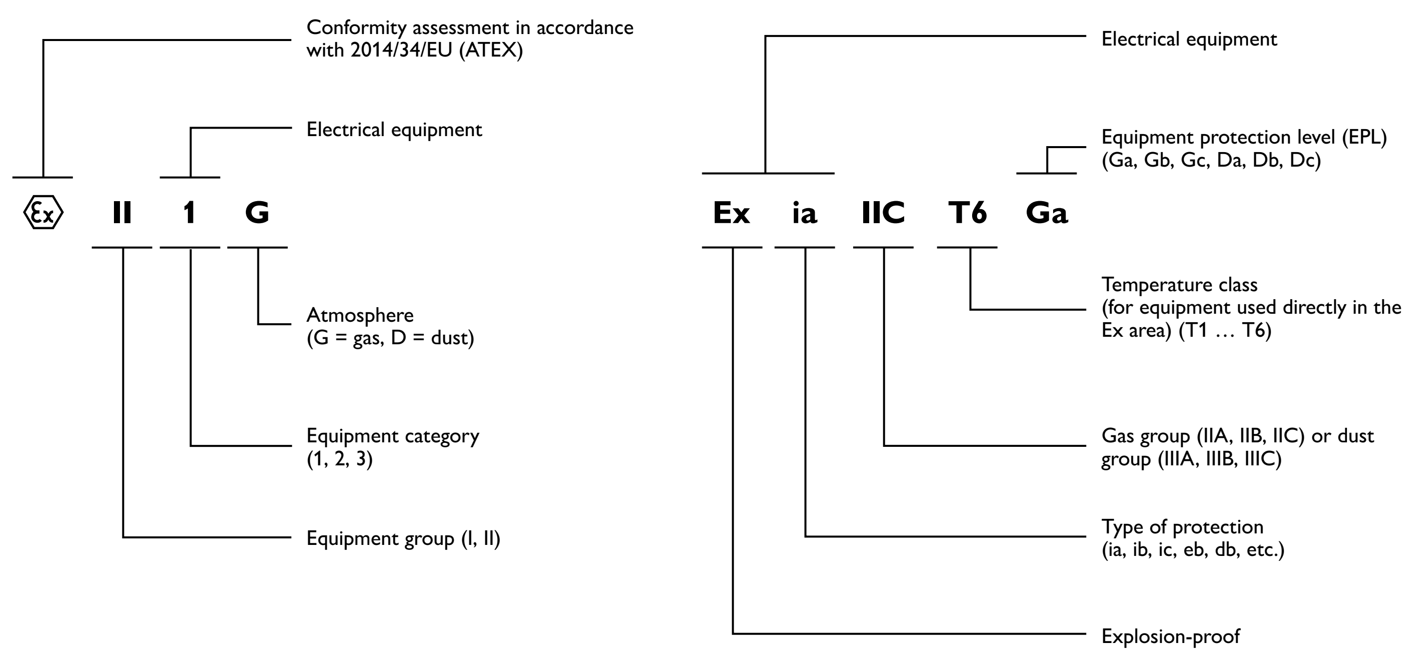
6 Marking of Ex products

In accordance with ATEX Directive 2014/34/EU and standard IEC/EN 60079-0, equipment must be labeled for potentially explosive areas. Devices for explosion protection in the EU must be labeled in accordance with both ATEX and the standard.

6.1 Marking of intrinsically safe equipment (Ex i field device)

In accordance with IEC/EN 60079-11, an intrinsically safe equipment is an electrical device in which all circuits are intrinsically safe. It is installed in the potentially explosive area.

Marking in accordance with ATEX Directive	Marking in accordance with IEC/EN 60079-0



6.2 Associated marking of equipment (Ex i signal conditioners)

Associated equipment in accordance with IEC/EN 60079-11 is an electrical device that contains both intrinsically safe and non-intrinsically safe circuits. It is designed in such a way that the non-intrinsically safe circuits cannot influence the intrinsically safe ones. The Ex i isolators are therefore particularly important, because they are absolutely necessary in every Ex i MCR circuit. The associated equipment is installed outside the Ex area and therefore does not require any information on the surface temperature.

Marking in accordance with ATEX Directive	Marking in accordance with IEC/EN 60079-0
Ex II (1) GD	**[Ex ia Ga] IIC**

Brackets = associated equipment

"1" and "Ex ia" in brackets means that the connected intrinsically safe equipment may be installed up to zone 0.

6.3 Other markings to be displayed

In addition to the marking, as shown in Sections 6.1. and 6.2., the company must be marked in accordance with the ATEX directive who is the notified body for production monitoring, the year in which the electrical device is manufactured, and conformity with other directive such as CE.

CE Ex II (1) G [Ex ia Ga] IIC

0344 BVS 08 ATEX E 054 X

19

Special conditions for safe use

Certificate number

Type-tested in accordance with 2014/34/EU (ATEX)

Year of EU type test certificate

Notified body

Year of manufacture of the device

Notified body for production monitoring

6.4 Relationship between equipment categories, EPL, and zones

The equipment protection level (EPL) has been introduced in standard IEC/EN 60079-0:2007 and specifies the equipment protection level of the device or component. The equipment protection level should be viewed in the same way as the equipment categories used in the ATEX Directive. The new standard now provides a way of assigning devices to zones that is simpler than marking them according to their type of protection.

	Equipment category in accordance with ATEX Directive 2014/34/EU	**Equipment protection level (EPL)**	**Zone**	**Type of danger**
Gas	1G	Ga	0	Continuous, long periods, frequent
	2G	Gb	1	Occasional
	3G	Gc	2	Not usually present, short periods only
Dust	1D	Da	20	Continuous, long periods, frequent
	2D	Db	21	Occasional
	3D	Dc	22	Not usually present, short periods only
Mining	M1	Ma		Continuous, long periods, frequent
	M2	Mb		Occasional

6.5 Identification in the European Union – ATEX directives

In Europe, the marking of equipment, components, and protective systems is based on the marking specified in directives and standards.

Examples of marking in accordance with ATEX Directive 2014/34/EU and EN 60079-0 for gas atmospheres

Gas atmosphere	**EU type test certificate number** **U: component** **X: special operating conditions**	**Marking ...**			
		... in accordance with ATEX		**... in accordance with standard EN 60079-0:2006**	**... in accordance with standard EN 60079-0:2009**
Electrical equipment	IBExU 09 ATEX 1030	CE	⟨Ex⟩ II 3 G	Ex-nA II T4	Ex-nA IIC T4 Gc
Associated equipment	BVS 08 ATEX E 094 X	CE 0344	⟨Ex⟩ II (1) G	[Ex ia] IIC	[Ex ia Ga] IIC
Component	KEMA 07 ATEX 0193 U	0344	⟨Ex⟩ II 2 G	Ex e II	Ex e IIC Gb

Examples of marking in accordance with ATEX Directive 2014/34/EU and EN 60079-0 for dust atmospheres

Dust atmosphere	**EU type test certificate number** **X: special operating conditions**	**Marking ...**			
		... in accordance with ATEX		**... in accordance with standard EN 61241:2006**	**... in accordance with standard EN 60079-0:2009**
Electrical equipment	PTB 00 ATEX 0000 X	CE	⟨Ex⟩ II 2 D	Ex tD A21 IP65 T80°C	Ex tb IIIC T80°C Db
Associated equipment	TÜV 00 ATEX 0000	CE	⟨Ex⟩ II [1] D	[Ex iaD]	[Ex ia Da] IIIC

6.6 Worldwide marking – IECEx

With the IECEx system, marking is purely derived from the requirements of the IEC standards.

Examples of labeling with IECEx certificate number and in accordance with IEC 60079-0

Gas atmosphere	**Number of the IECEx Certificate of Conformity** **U: component** **X: special installation conditions**	**Marking …**	
		… in accordance with standard IEC 60079-0:2004	**… in accordance with standard IEC 60079-0:2007**
Electrical equipment	IECEx IBE 09.0002X	Ex-nA II T4	Ex-nA IIC T4 Gc
Associated equipment	IECEx BVS 08.035X	[Ex ia] IIC	[Ex ia Ga] IIC
Component	IECEx KEM 07.0057U	Ex e II	Ex e IIC Gb

Examples of labeling with IECEx certificate number and in accordance with IEC 60079-0

Dust atmosphere	**Number of the IECEx Certificate of Conformity** **U: component** **X: special installation conditions**	**Marking …**	
		… in accordance with old standard IEC 61241-0:2005	**… in accordance with standard IEC 60079-0:2007**
Electrical equipment	IECEx IBE 00.0000X	Ex tD A21 IP65 T80°C	Ex t IIIC T80°C Db
Associated equipment	IECEx BVS 00.0000X	[Ex iaD]	[Ex ia Da] IIIC

6.7 Identification in North America – NEC and CEC

In North America, approval can be obtained for associated intrinsically safe equipment (Associated Apparatus) either in accordance with the division concept (NEC 500/ UL 12.12.01 in conjunction with UL 913) or the zone concept (NEC 505 and NEC 506/UL 60079-0 ff.). Since the marking of the UL 60079 series corresponds to the IEC 60079 series due to extensive harmonization, only the example of a marking in accordance with the division concept is shown here.

Examples of labeling with IECEx certificate number and in accordance with IEC 60079-0

Classification of the equipment		1M68		
Approval body in the USA: here UL	c for Canada; us for the USA	c UL us		
		Listed CD-No: 12345678	Control drawing No. (control document)	
	UL 12.12.01	Suitable for Class I, Div. 2, Groups A, B, C and D installation;	Can be used in Div 2* for Class I: gases	A: acetylene B: hydrogen C: ethylene D: propane
	UL 913	providing intrinsically safe circuits for use in		
		Class I, Div. 1, Groups A, B, C, and D;	Gases	Suitable for circuits in Div 1* * In accordance with NEC 500
		Class II, Div. 1, Groups E, F, and G; and	Dusts	
		Class III, Hazardous Locations	Fibers	

7 Installation of systems in potentially explosive areas

If systems are installed in potentially explosive areas, a large number of precautionary measures must be taken. The operator is responsible for safe system operation and for the safety of personnel. In addition, they must ensure that the minimum requirements of the Operator Directive are applied.

7.1 Standards and directives

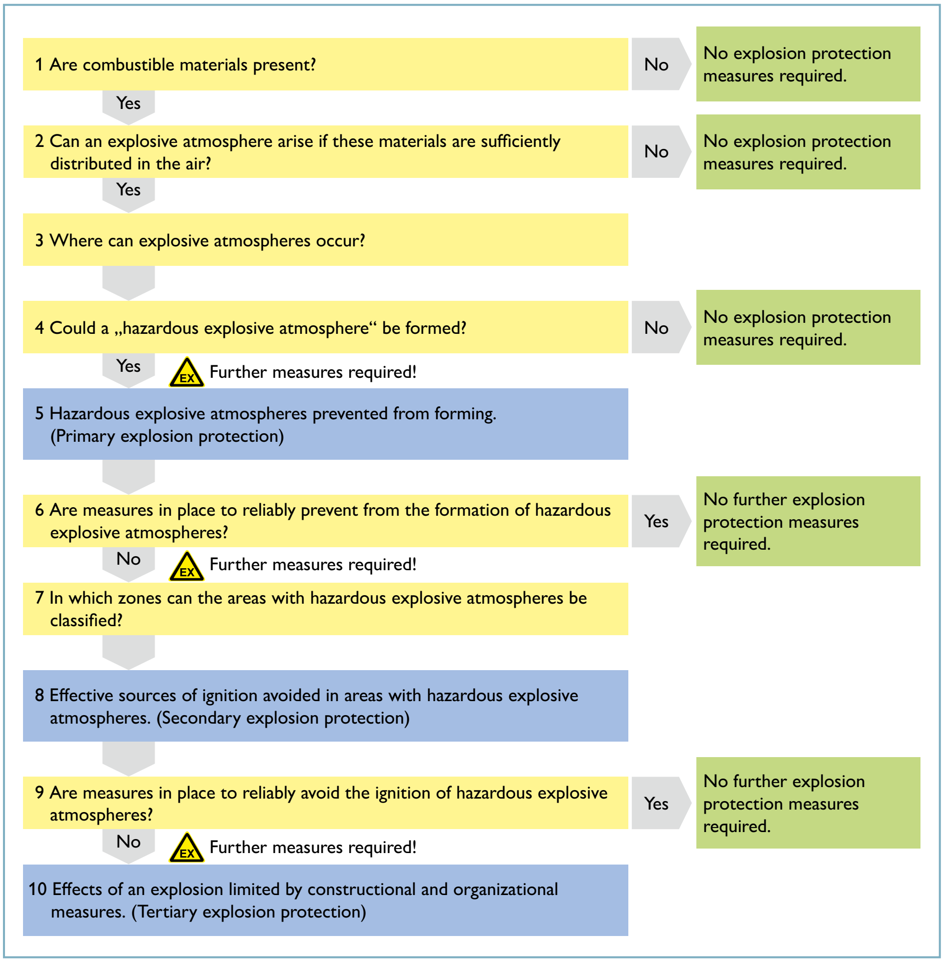
Directive 1999/92/EC on the "minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres" relates to the operation of potentially explosive systems and is therefore aimed at operators. In accordance with Directive 1999/92/EC, the latter must assess, among other things, the explosion hazard of the plant (risk analysis), ensure the minimum regulations, divide the system into hazardous zones, and create an explosion protection document.

The requirements to be observed are described and deepened in the IEC/EN 60079-10 and IEC/EN 60079-14 standards. In IEC/EN 60079-10, you find further details on zone classification and in IEC/EN 60079-14 you find details on the configuration, selection, and installation of electrical systems: for example, requirements on cable and line systems, details on type of protection-related installation specifications, and lightning protection measures.

7.2 Risk analysis

The operator of a system must carry out a detailed assessment. This is based on standards IEC/EN 60079-10, IEC/EN 60079-14, and EN 11271, for example. The zones are determined and the permitted items of equipment selected based on this assessment. Every system must be examined with respect to its specific characteristics. The possible risks associated with an explosion occurring despite these measures must be examined in advance: for example, can chain reactions occur, what is the extent of damage to the buildings, and what effect does the explosion have on other parts of the system? It is possible for reciprocal effects that could never occur in the individual system to occur with neighboring systems. The risk assessment is usually carried out by a team which looks at all the relevant aspects of the system. In case of doubt, we recommend consulting additional experts. Risk assessment is the basis for all other measures to the point of system operation. These assessments must be recorded in the explosion protection document. The guide referred to in Article 11 of Directive 1999/92/EC contains the following methodical procedure (flowchart derived):

Assessment flowchart for identifying and preventing explosion hazards:



7.3 Explosion protection document

The documentation is crucial for the safe operation of the system within the potentially explosive area. It is created prior to installation and must always be kept up to date. If changes are made to the system, all the influencing variables described must be taken into consideration.

Example for the structure of the documentation	
Person responsible for the object	Identified by name
Description of the structural and geographical characteristics	Plan of site and building, ventilation and air supply
Description of procedures	Description of the system from the point of view of explosion protection
Materials data	List of data with characteristics relevant to an explosion
Risk assessment	See guide above
Protection concepts	Zone classification, protection types applied
Organizational measures	Training, written instructions, clearance for work

8 Designing and installing intrinsically safe circuits

To ensure that the intrinsically safe circuit is actually safe, the user or operator must carry out and implement the measures described in this section: from evaluating the suitability of the equipment with regard to the required level of protection and the available material groups, to proof of intrinsic safety, right through to installation.

8.1 Designing intrinsically safe circuits

The operator determines the zone, the group, and the temperature class for the field device, based on the risk analysis which has been carried out. When selecting suitable devices, first check whether the devices are approved for the intended application. This can be done, for example, by marking the equipment in accordance with the table "Checking the suitability of the device using the marking" table:

Intrinsically safe equipment (field device)	Evaluation of the Ex marking	Associated equipment
⟨Ex⟩ II **1** G Ex ia IIB T6 **Ga**	Device category and device protection level (EPL) of the intrinsically safe equipment (field device) correspond to the specified zone.	
⟨Ex⟩ II **1** G Ex **ia** IIB T6 **Ga**	Type of protection is permitted in the specified zone.	
⟨Ex⟩ II 1 **G** Ex ia **IIB T6** Ga	The device is approved for use in the prevailing gas atmosphere.	
	As such, the corresponding equipment is marked with brackets and without specification of the temperature class/limits.	⟨Ex⟩ II **(1)** G **[**Ex ia Ga**]** IIC
⟨Ex⟩ II **1 G** Ex ia IIB T6 **Ga**	The device category and device protection level (EPL) of the associated equipment at least correspond the device category and the device protection level (EPL) of the field device.	⟨Ex⟩ II **(1) G** [Ex ia **Ga**] IIC
⟨Ex⟩ II 1 G **Ex ia** IIB T6 Ga	Type of protection of the associated equipment matches that of the intrinsically safe equipment (field device).	⟨Ex⟩ II (1) G **[Ex ia** Ga] IIC
⟨Ex⟩ II 1 G Ex ia **IIB** T6 Ga	The associated equipment is approved for the same group or one of a higher order.	⟨Ex⟩ II (1) G [Ex ia Ga] **IIC**

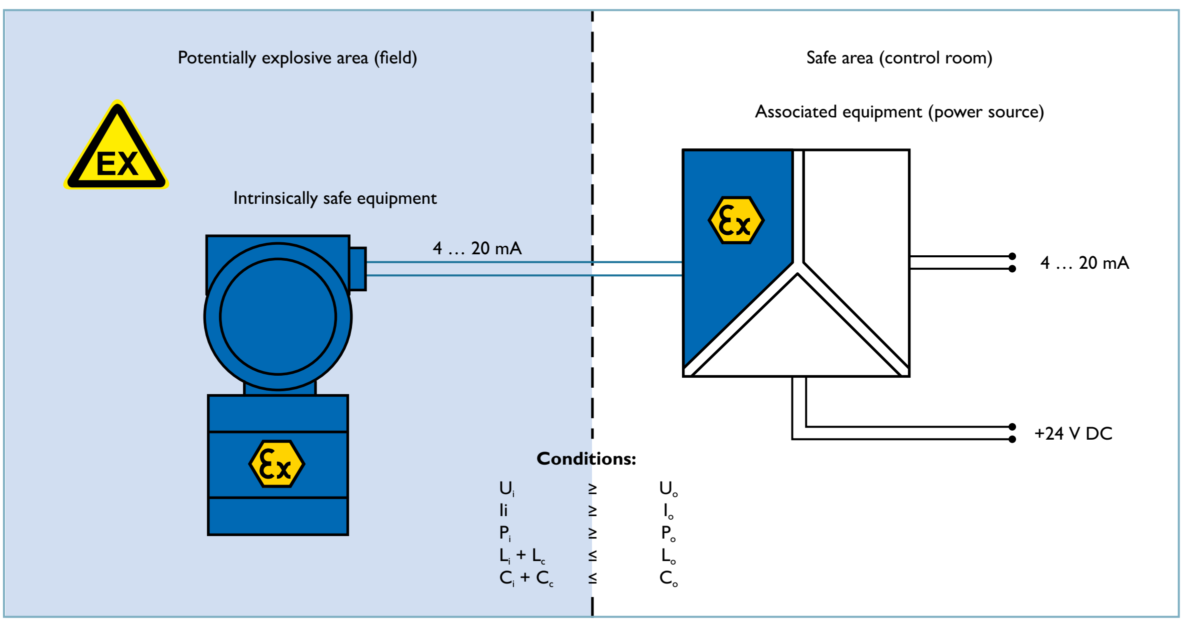
8.2 Proof of intrinsic safety

The intrinsically safe circuit generally consists of the intrinsically safe equipment, the associated equipment, and the connecting cables. To ensure that the device combination selected by the operator is actually intrinsically safe, proof of intrinsic safety must be performed for the corresponding circuit.

The installer or operator is responsible for providing proof of intrinsic safety, not the manufacturer. This must be implemented in accordance with standard IEC/EN 60079-14 and, if necessary, other national standards and installation regulations.

8.2.1 Intrinsically safe circuits with one current source

Generally speaking, intrinsically safe circuits have only one energy source or associated item of equipment. In the first step, the criteria are checked in accordance with the table “Checking the suitability of the device using the marking” table in Section 8.1. To aid planning and installation, it is advisable to keep the operating instructions for the equipment being used close at hand. The necessary parameters, that is, the safety data for verifying intrinsic safety, are taken from these. The next step is to check the safety-related data of the intrinsically safe circuit (voltage, current, power, capacitance, and inductance) in accordance with the figure below.



To demonstrate intrinsic safety, the five conditions specified in the figure “Criteria for fulfilling intrinsic safety” must be met.

Safety-related parameters and their abbreviations

Common designations	Europe	USA/Canada
For intrinsically safe equipment (field device):		
Max. input voltage	U_i	V_{max} / U_i
Max. input power	I_i	I_{max}
Max. internal capacity (or concentrated capacity in the intrinsically safe circuit)	C_i	C_i
Max. internal inductance (or concentrated inductance in the intrinsically safe circuit)	L_i	L_i
For associated equipment:		
Max. output voltage	U_o	V_{oc}
Max. output power	I_o	I_{sc}
Max. external (connectable) capacitance	C_o	C_a
Max. external (connectable) inductance	L_o	L_{ex}
For cable/line:		
Cable/line capacity	C_c	C_{cable}
Cable/line inductance	L_c	L_{cable}

In the intrinsically safe circuit, all capacitances and inductances must be taken into account and compared with capacitance C_o and inductance L_o of the associated equipment. In practice, it is particularly important to observe the capacitance, since this can restrict the length of cables or lines substantially. As a guide, capacitance C_c can be taken to be approximately 140 … 200 nF/km and inductance L_c approximately 0.8…1 mH/km. If in any doubt, always assume the worst case.

Verification of intrinsic safety for simple intrinsically safe circuits

The verification of an intrinsically safe circuit with linear characteristic curves described above is permitted if a simple intrinsically safe circuit is available. There are no external concentrated capacitances (C_i) and no external concentrated inductances (L_i) present. The certified values for C_o and L_o can be fully utilized.

Verification of intrinsic safety for mixed intrinsically safe circuits

A mixed intrinsically safe circuit exists when external concentrated capacitances (C_i) and/or external concentrated inductances (L_i) are present.

The verification of intrinsic safety verification described above is also permitted if a mixed intrinsically safe circuit is present and the following condition is met: total value of L_i <1% of L_o or total value of C_i <1% of C_o. The certified values for C_o and L_o may also be fully utilized in this case.

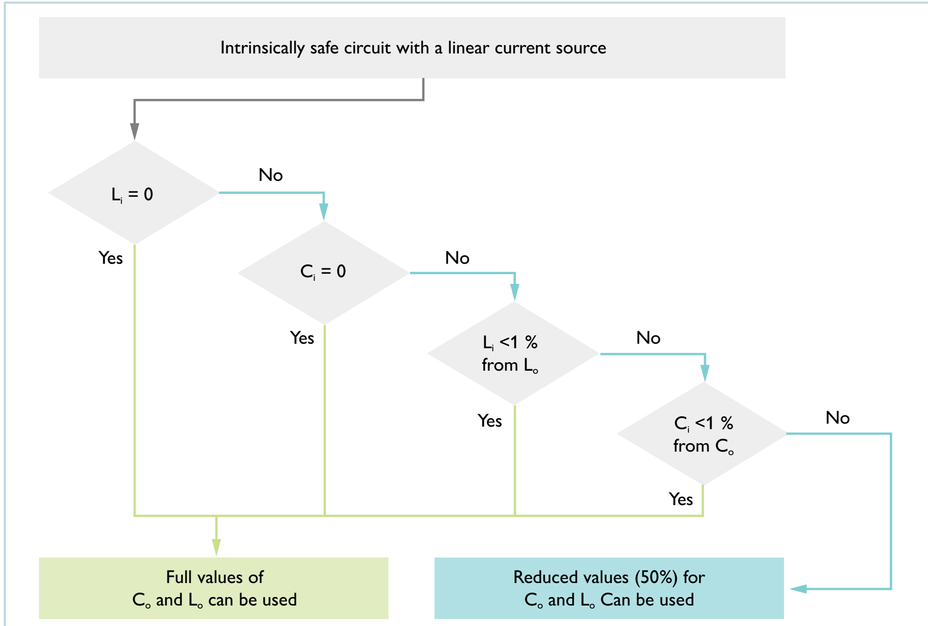
However, if we have a mixed intrinsically safe circuit with the condition that L_i ≥1% of L_o and Ci ≥1% of Co, then only 50% of the certified values for Co and Lo may be utilized ("50% rule"). The following therefore applies accordingly:

$$C_i + C_c \leq 0.5\ C_o$$

$$L_i + L_c \leq 0.5\ L_o$$

For better understanding, the assessment of whether the 50% rule is to be applied is shown as a graph in the following figure:

If the 50% rule is to be applied, certified value pairs for C can also be used for the associated equipment C_o and L_o are made available. This is the case with the Ex i isolator series MACX Analog or MINI Analog, for example. This means that larger cable lengths can be achieved compared to the 50% rule. These value pairs can be found in the operating instructions, in the data sheet, or in the EU type test certificate for the corresponding equipment.



Graphical representation for the application assessment of the 50% rule in accordance with IEC/EN 60079-11

8.2.2 Intrinsically safe circuits with more than one current source

In some other cases, there is more than one current source or more than one corresponding equipment in an intrinsically safe circuit. In these cases, proof of the intrinsic safety must be demonstrated using theoretical calculations or tests with the spark tester (in accordance with IEC/EN 60079-11). Whether or not a current addition is present must be taken into account. For these cases, it is therefore recommended to have the evaluation performed by an expert.

Examples for the interconnection of several intrinsically safe circuits with linear current-voltage characteristic curves are listed in Appendix A and Appendix B of IEC/EN 60079-14:2013. When items of associated equipment with non-linear characteristic curves are interconnected, the evaluation based on the no-load voltage and the short-circuit current does not yield a result. However, the calculations can be performed on the basis of PTB report PTB-ThEx-10, "Interconnection of non-linear and linear intrinsically safe circuits". This has been incorporated into IEC/EN 60079-25 (intrinsically safe systems). Here, graphical methods are used to evaluate intrinsic safety up to zone 1.

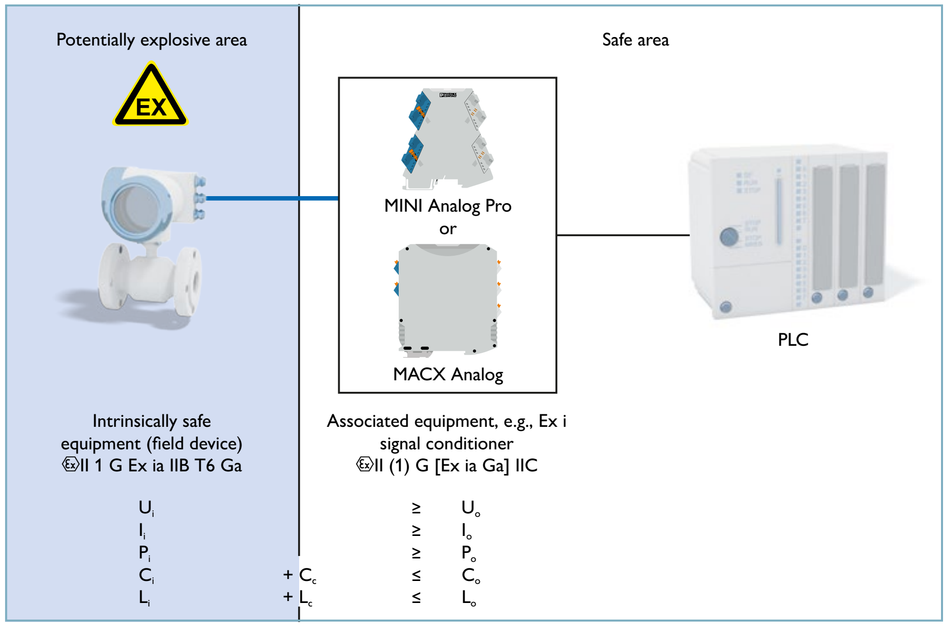
8.3 Examples for proof of intrinsic safety

The following shows examples for the design of intrinsically safe circuits based on typical applications such as analog IN and OUT, digital IN and OUT, and temperature measurements. If the five conditions from the following figure are met, proof is provided that the considered combination of the intrinsically safe equipment, the associated equipment, and the connecting cables is intrinsically safe.

For proof of intrinsic safety, the cable capacities and inductances can be found in the data sheets of the cables. Alternatively, the following worst-case specifications can be assumed in accordance with IEC/EN 60079-14 for cable capacitances and cable capacities:

Cable capacitance: 200 nF/km
Cable inductances: 1 mH/km

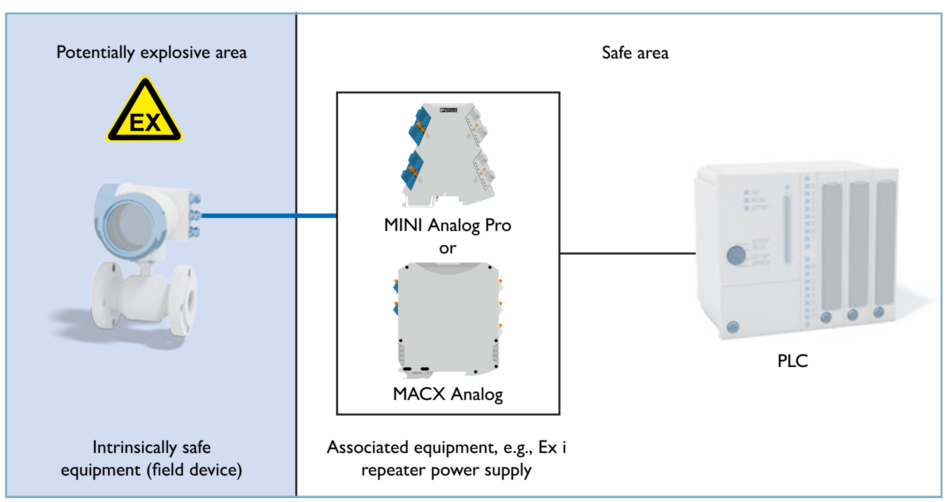
The parameters specified by the cable manufacturers are usually lower.



Conditions for fulfilling proof of intrinsic safety

8.3.1 Analog IN

Case 1: Ex i repeater power supply
The device transmits analog 4 ... 20 mA signals from a passive measuring transducer from the Ex area to a controller and supplies the measuring transducer with power.



Comparison of the safety data

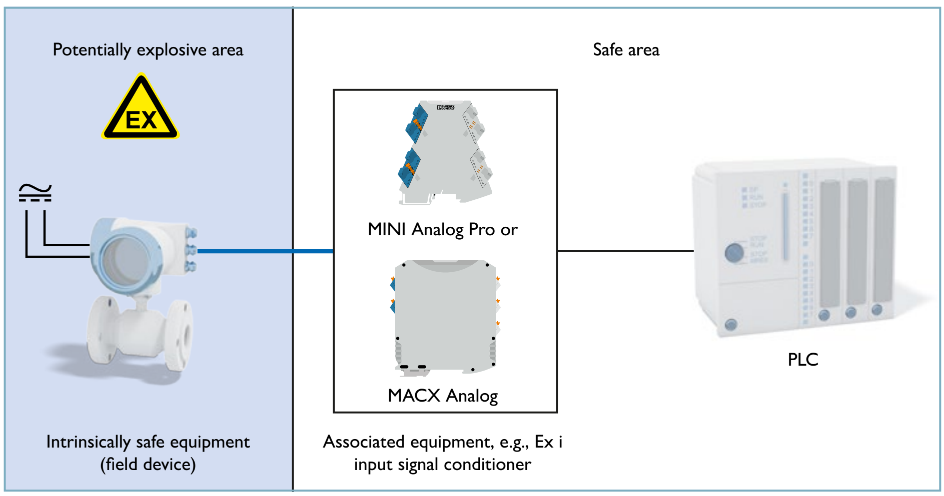
Intrinsically safe equipment: Pressure transmitter		**Cables/lines[1] Length = 500 m**			**Associated equipment: Ex i repeater power supply MACX MCR-EX-RPSSI-I**		**Conditions met?**
U_i	30 V			≥	U_o	25.2 V	Yes[2]
I_i	100 mA			≥	I_o	93 mA	Yes[2]
P_i	750 mW			≥	P_o	587 mW	Yes[2]
C_i	0 nF	$+C_c$	+90 nF	≤	C_o	IIC: 107 nF	Yes[2]
L_i	0 mH	$+L_c$	+0.5 mH	≤	L_o	IIC: 3 mH	Yes[2]

[1] Assumption: C_c = 180 nF/km, L_c = 1 mH/km
[2] Conclusion: The conditions for fulfilling the proof of intrinsic safety are therefore met.

Case 2: Input signal conditioner, Ex i

The device transmits analog 0/4 ... 20 mA signals from an active measuring transducer (4-wire measuring transducer) from the Ex area to a controller in an electrically isolated manner. The active measuring transducer is not supplied with energy by the Ex i input signal conditioner.

In this case, the field device and not the associated equipment is the source. This changes the approach for verifying intrinsic safety in accordance with the following table:



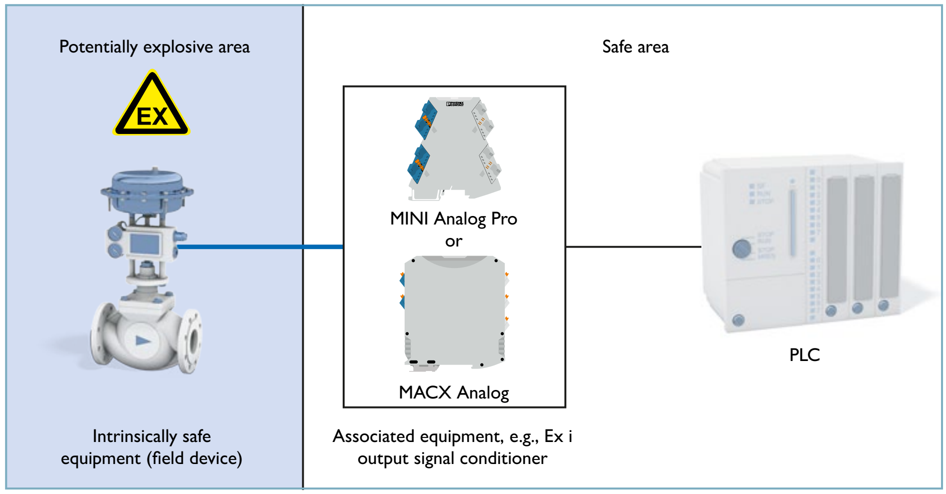
Comparison of the safety data

Associated equipment: Ex i input signal conditioner MACX MCR-EX-RPSSI-I		**Cables/lines[1] Length = 500 m**			**Equipment: Flow transducer**		**Conditions met?**
U_i	30 V			≥	U_o	28.3 V	Yes[3]
I_i	150 mA			≥	I_o	130 mA	Yes[3]
P_i[2]	-			-	P_o	920 mW	Yes[3]
C_i	0 nF	$+C_c$	+90 nF	≤	C_o	IIC: 100 nF	Yes[3]
L_i	0 mH	$+L_c$	+0.5 mH	≤	L_o	IIC: 2 mH	Yes[3]

[1] Assumption: C_c = 180 nF/km, L_c = 1 mH/km
[2] In the approvals P_i is not listed. This means that in this circuit, P_i is not relevant and therefore does not need to be considered here.
[3] Conclusion: The conditions for fulfilling the proof of intrinsic safety are therefore met.

8.3.2 Analog OUT

Ex i output signal conditioners transmit analog 0/4 ... 20 mA signals from a controller to an actuator in the Ex area using an electrically isolated method.



Scenario 1: Ex i output signal conditioner in a mixed intrinsically safe circuit without 50% rule
Comparison of the safety data

Intrinsically safe equipment: Control valve		**Cables/lines[1] Length = 250 m**			**Associated equipment: Ex i output signal conditioner MINI MCR-EX-IDS-I-I-PT**		**Conditions met?**
U_i	28 V			≥	U_o	26.4 V	Yes[2]
I_i	110 mA			≥	I_o	98 mA	Yes[2]
P_i	770 mW			≥	P_o	647 mW	Yes[2]
C_i	5 nF	$+C_c$	+45 nF	≤	C_o	IIC: 89 nF	Yes[2]
L_i	0 mH	$+L_c$	+0.25 mH	≤	L_o	IIC: 2 mH	Yes[2]

[1] Assumption: C_c = 180 nF/km, L_c = 1 mH/km
[2] Conclusion: The conditions for fulfilling the proof of intrinsic safety are therefore met.

A mixed intrinsically safe circuit is present (external concentrated capacitances (C_i) and/or external concentrated inductances (L_i) present), which meets the following condition: total value of L_i <1% of L_o or total value for C_i <1% of C_o. Thus, the certified values for C may$_o$ and L_o may be fully exploited.

Case 2: Ex i output signal conditioner in a mixed intrinsically safe circuit with 50% rule
Comparison of the safety data

Intrinsically safe equipment: Control valve		**Cables/lines[1] Length = 100 m**			**Associated equipment: Ex i output signal conditioner MINI MCR-EX-IDS-I-I-PT**		**Conditions met?**
U_i	28 V			≥	U_o	26.4 V	Yes[2]
I_i	110 mA			≥	I_o	98 mA	Yes[2]
P_i	770 mW			≥	P_o	647 mW	Yes[2]
C_i	5 nF	$+C_c$	+20 nF	≤	$0.5^{*}C_o$	IIC: 44.5 nF	Yes[2]
L_i	0.3 mH	$+L_c$	+0.1 mH	≤	$0.5^{*}L_o$	IIC: 1 mH	Yes[2]

[1] Assumption: C_c = 180 nF/km, L_c = 1 mH/km
[2] Conclusion: The conditions for fulfilling the proof of intrinsic safety are therefore met.

A mixed intrinsically safe circuit is present (external concentrated capacities (C_i) and/or external concentrated inductances (L_i) are present), which meets the following condition: total value of $L_i \geq$ 1% of L_o and total value of $C_i \geq$ 1% of C_o. Thus, the certified values for C may$_o$ and L_o are not fully exploited. They must be reduced by 50%.

The following applies accordingly:

$C_i + C_c \leq 0.5\ C_o$

$L_i + L_c \leq 0.5\ L_o$

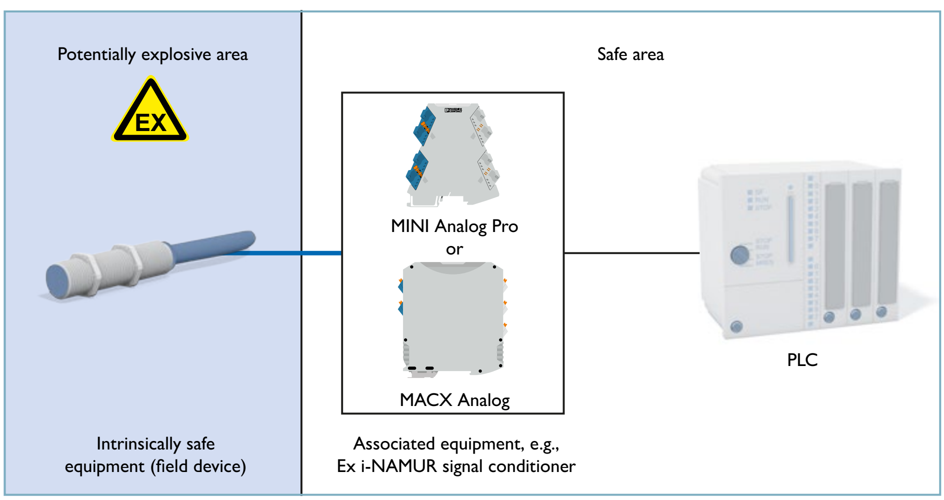
In order to enable longer cable lengths, certified value pairs for C_o and L_o can be provided for the associated equipment if the 50% rule must be applied. This is the case with the Ex i isolator series MACX Analog or MINI Analog, for example.

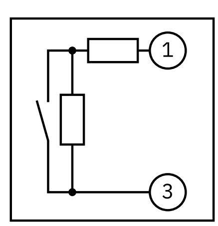
8.3.3 Digital IN

Ex i NAMUR signal conditioners transmit binary signals from sensors in the field to the controller using an electrically isolated method. This signal is created in the field by a switch or a NAMUR sensor. On the output side of the signal conditioner, the signal is forwarded to the controller as a binary signal either by a relay or by a transistor.

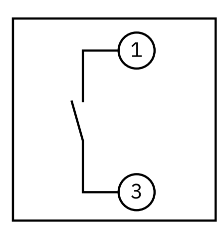
An additional resistance circuit enables wire-break detection to be performed even for simple switches.

The resistance ensures that a minimum current is always flowing, even when the switch is open. In this way, a line break can be identified. In the case of simple electrical equipment, such as, simple switches, only the inductance and capacitance values of the cables or lines are used for the comparison of safety data. For additional requirements relating to simple electrical equipment, see page 27.





With wire-break detection



Without wire-break detection

Comparison of the safety data

Intrinsically safe equipment: NAMUR sensors		Cables/lines[1] Length = 500 m			Associated equipment: Ex i signal conditioner MINI MCR-EX-NAM-RO-PT		Conditions met?
U_i	13.5 V			≥	U_o	10.1 V	Yes[2]
I_i	37 mA			≥	I_o	10.9 mA	Yes[2]
P_i	125 mW			≥	P_o	28 mW	Yes[2]
C_i	50 nF	$+C_c$	+90 nF	≤	C_o	IIC: 2.87 µF	Yes[2]
L_i	0.2 mH	$+L_c$	+0.5 mH	≤	L_o	IIC: 300 mH	Yes[2]

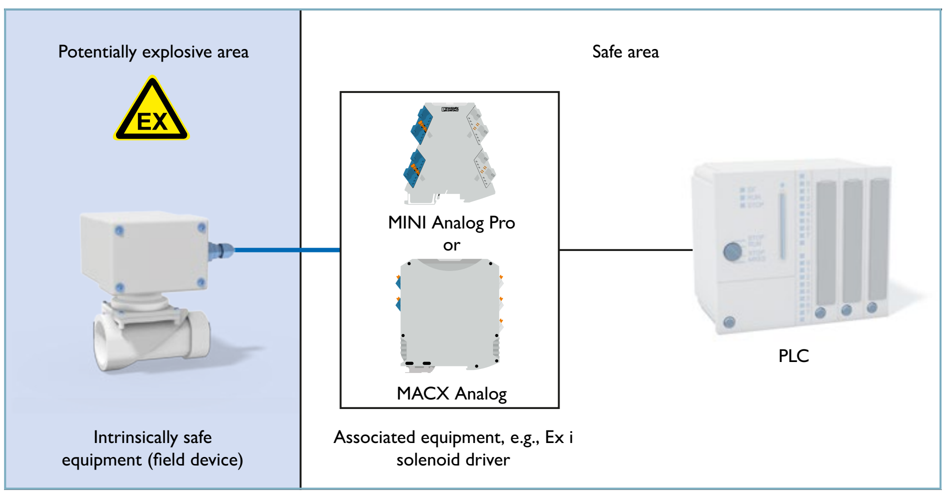
1) Assumption: C_c= 180 nF/km, L_c= 1 mH/km
2) Conclusion: The conditions for fulfilling the proof of intrinsic safety are therefore met.

A mixed intrinsically safe circuit is present (external concentrated capacitances (C_i) and/or external concentrated inductances (L_i) present), which meets the following condition: total value of L_i <1% of L_o or total value for C_i <1% of C_o. Thus, the certified values for C may$_o$ and L_o may be fully exploited.

8.3.4 Digital OUT

Ex i solenoid drivers link a switch or voltage source installed in the safe area to a field device using an electrically isolated method. Intrinsically safe solenoid valves, alarm modules or other intrinsically safe devices can be connected, and simple electrical equipment such as LEDs can be operated.

The dimensions of a solenoid driver with a solenoid valve are described in the following as an example. In addition to verifying intrinsic safety, this also includes checking the function data:



Example for the Ex i MACX MCR-EX-SL-SD-24-48-LP solenoid driver
Comparison of the safety data

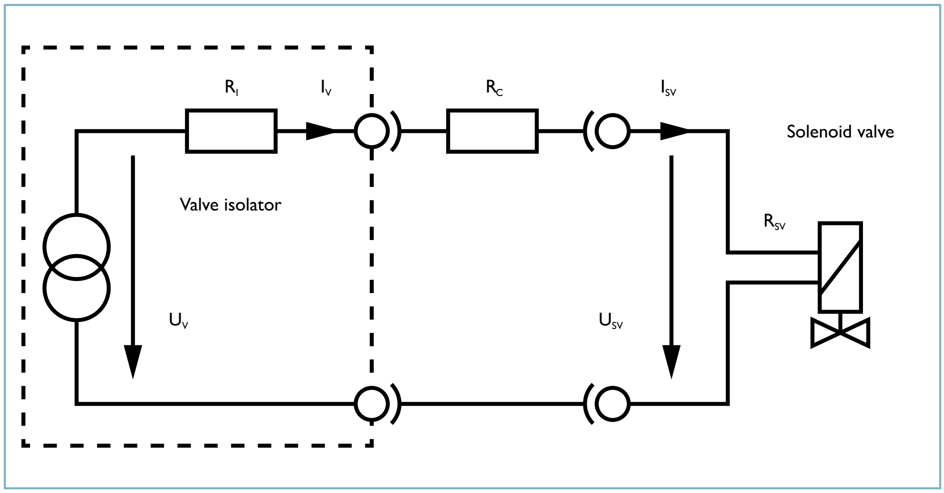
Intrinsically safe equipment: Solenoid valves		Cables/lines[1] Length = 100 m			Associated equipment: Ex i solenoid driver MACX MCR-EX-SL-SD-24-48-LP		Conditions met?
U_i	28 V			≥	U_o	27.7 V	Yes[2]
I_i	115 mA			≥	I_o	101 mA	Yes[2]
P_i	1.6 W			≥	P_o	697 mW	Yes[2]
C_i	0 nF	$+C_c$	+18 nF	≤	C_o	IIC: 80 nF	Yes[2]
L_i	0 mH	$+L_c$	+0.1 mH	≤	L_o	IIC: 5.2 mH	Yes[2]

1) Assumption: C_c= 180 nF/km, L_c= 1 mH/km
2) Conclusion: The conditions for fulfilling the proof of intrinsic safety are therefore met.

Checking function data

In addition to proof of intrinsic safety, functional data must also be checked. Especially with solenoid drives, this can be challenging, as there is no standard, such as with the NE43 for analog 4 ... 20 mA signals.

The following example illustrates how the test can be performed for the functional compatibility of the solenoid valve and the solenoid driver.



Schematic diagram of the connection of a solenoid valve with a solenoid driver

Key for schematic diagram

R_i	=	Internal resistance of the valve isolator
U_v	=	Guaranteed voltage of the valve isolator without load
R_c	=	Maximum permissible cable resistance when valve isolator and valve are interconnected
R_{sv}	=	Effective coil resistance of the solenoid valve (the copper resistance of the winding depends on the ambient temperature)
I_v	=	Maximum current that the valve isolator can supply
I_{sv}	=	Current needed by the solenoid coil in order for the valve to pick up or be stopped
U_{sv}	=	Voltage that is present at the coil with ISV (the copper resistance of the winding depends on the ambient temperature)

The following conditions must be met for the function to be guaranteed:

1. $I_v \geq I_{sv}$
2. $R_c = \frac{U_v}{Is_v} - R_i - R_{sv} >> 0\ \Omega$

1. Function data check: Values of the solenoid driver:
$U_v = 24$ V, $R_i = 276\ \Omega$, $I_v = 48$ mA
Solenoid valve values:
R_{sv} (65°C) = 566 Ω, $I_{sv} = 23$ mA
$I_v = 48$ mA $\geq I_{sv} = 23$ mA

This means that the maximum current which the solenoid driver can supply is sufficient for operating the solenoid coil.

2. Determining the max. permissible cable resistance:

$$R_c = \frac{U_v}{Is_v} - R_i - R_{sv} = \frac{24\ \text{V}}{0.023\ \text{A}} - 276\ \Omega - 566\ \Omega = 201.5\ \Omega$$

The calculation shows that the cable resistance may be 201.5 Ω without affecting the interconnection function.
Recommendation: For the valve to function, Rc ≥ should be 25 Ω in order to have sufficient reserves for longer cable lengths.

Guide values for cables and lines:

Conductor resistance (supply/return line)	0.5 mm² : 72 Ω/km 0.75 mm² : 48 Ω/km 1.5 mm² : 24 Ω/km
Cable capacitance	Approx. 180 nF/km
Cable inductance	Approx. 0.8 mH/km

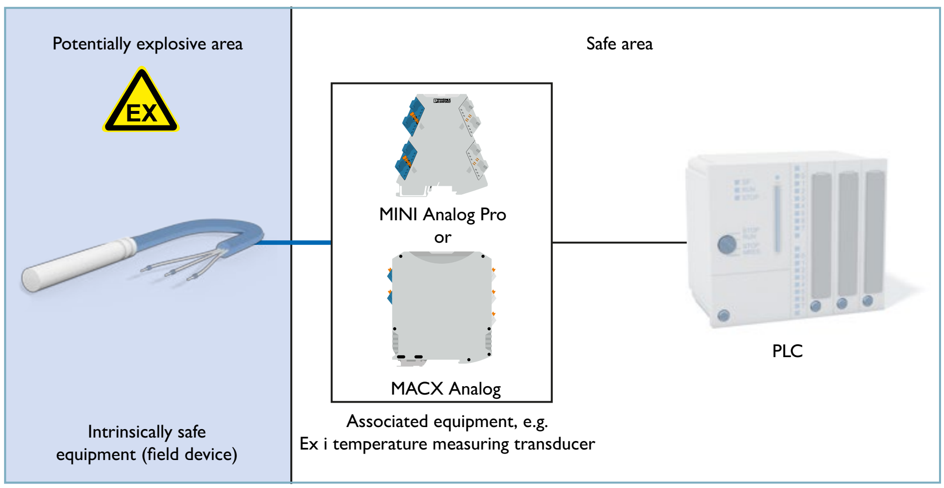
With a power cross section of 0.5 mm² the maximum possible cable length is 2.798 km. However, since safety data from the Ex approval (see proof of intrinsic safety) must also be taken into account, the maximum permissible cable length in the example is 444 m for group IIC. A cable length of 3.66 km could be implemented for Group IIB with $L_o = 20$ mH and $C_o = 660$. Here, the function data then limits the maximum possible cable length to 2.798 km.

8.3.5 Temperature measurement

Temperature measuring transducers convert measuring signals from temperature sensors into analog standard signals (e.g., 0/4 ... 20 mA). Temperature sensors are designed as resistance thermometers (e.g., Pt 100, etc.) and thermocouples (e.g., J, K). In accordance with EN 60079-11, these can be regarded as simple electrical equipment, as they are passive (for further information on the topic of “Simple electrical equipment”, see Section 4.3.5 on page 27). Simple electrical equipment must meet the requirements of EN 60079-11 and must not impair the intrinsic safety of the circuit in which it is used. However, they are not covered under the ATEX Directive 2014/34/EU. If certified, intrinsically safe sensors are used; this reduces the amount of testing work required.

There are two possibilities for converting the temperature signal into a standard signal for the controller:

1. Temperature measurement using an Ex i temperature measuring transducer
The measuring signal of the Pt 100 resistance thermometer is routed to the temperature measuring transducer via a signal line. In the measuring transducer, the temperature signal is converted into a standard signal and the intrinsically safe and non-intrinsically safe circuits are isolated simultaneously. The measuring transducer is an item of associated equipment with intrinsic safety Ex ia type of protection. It is installed in a control cabinet in the safe area.



Comparison of the safety data

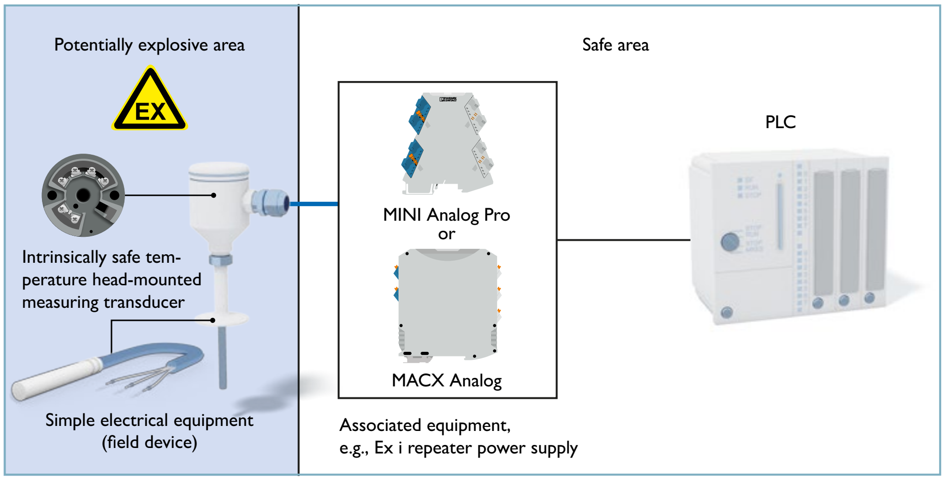
Intrinsically safe equipment: Resistance thermometer		**Cables/lines[1] Length = 100 m**			**Associated equipment: Ex i temperature measuring transducer MACX MCR-EX-RTD-I**		**Conditions met?**
U_i	7 V			≥	U_o	6 V	Yes[2]
I_i	400 mA			≥	I_o	16.8 mA	Yes[2]
P_i	330 mW			≥	P_o	25.2 mW	Yes[2]
C_i	150 nF	$+C_c$	+18 nF	≤	C_o	IIC: 600 nF	Yes[2]
L_i	0.027 mH	$+L_c$	+0.1 mH	≤	L_o	IIC: 100 mH	Yes[2]

[1] Assumption: C_c= 180 nF/km, L_c= 1 mH/km
[2] Conclusion: The conditions for fulfilling the proof of narrowing reliability are therefore met.

A mixed intrinsically safe circuit is present (external concentrated capacitances (C_i) and/or external concentrated inductances (L_i) present), which meets the following condition: total value of L_i <1% of L_o or total value for C_i <1% of C_o. Thus, the certified values for C may$_o$ and L_o may be fully exploited.

2. Temperature measurement using Ex i temperature transmitter and Ex i repeater power supply

The measuring signal of the Pt 100 resistance thermometer is converted into a standard signal in the vicinity of the measuring point, that is, in potentially explosive areas. Loop-powered Ex i temperature measuring transducers and Ex i temperature transmitters are used for this. The standard signal is then routed to an Ex i repeater power supply. It is installed in the safe area. In the Ex i repeater power supply, the intrinsically safe and non-intrinsically safe circuit is separated. The safety-related data of the electrical equipment, the intrinsically safe temperature transmitter, and the repeater power supply as the associated equipment must be compared. In this case, proof of intrinsic safety must therefore be carried out twice.



Comparison of safety-related data for the Ex i temperature transmitter with Ex i repeater power supply

Intrinsically safe equipment: FA MCR-EX-HT-1TS-I-OLP Ex i temperature transmitter		**Cables/lines[1] Length = 100 m**			**Associated equipment: Ex i repeater power supply MINI MCR-EX-RPSS-I-I**		**Conditions met?**
U_i	30 V			≥	U_o	26.4 V	Yes[2]
I_i	100 mA			≥	I_o	98 mA	Yes[2]
P_i	800 mW			≥	P_o	647 mW	Yes[2]
C_i	0 nF	$+C_c$	+18 nF	≤	C_o	IIC: 92 nF	Yes[2]
L_i	0 mH	$+L_c$	+0.1 mH	≤	L_o	IIC: 2 mH	Yes[2]

[1] Assumption: C_c= 180 nF/km, L_c= 1 mH/km
[2] Conclusion: The conditions for fulfilling the proof of narrowing reliability are therefore met.

Comparison of the safety data of the Ex i resistance thermometer with Ex i temperature transmitter

Intrinsically safe equipment: Resistance thermometer		**Cables/lines[1] Length = 100 m**			**Intrinsically safe equipment: Ex i temperature transmitter FA MCR-EX-HT-TS-I-OLP**		**Conditions met?**
U_i	7 V			≥	U_o	4.3 V	Yes[2]
I_i	400 mA			≥	I_o	4.8 mA	Yes[2]
P_i	330 mW			≥	P_o	5.2 mW	Yes[2]
C_i	150 nF	$+C_c$	+18 nF	≤	C_o	IIC: 3 µF	Yes[2]
L_i	0.027 mH	$+L_c$	+0.1 mH	≤	L_o	IIC: 50 mH	Yes[2]

[1] Assumption: C_c= 180 nF/km, L_c= 1 mH/km
[2] Conclusion: The conditions for fulfilling the proof of narrowing reliability are therefore met.

A mixed intrinsically safe circuit is present (external concentrated capacitances (C_i) and/or external concentrated inductances (L_i) present), which meets the following condition: total value of L_i <1% of L_o or total value for C_i <1% of C_o. Thus, the certified values for C may$_o$ and L_o may be fully exploited.

8.4 Installation of intrinsically safe circuits

The entire intrinsically safe circuit must be protected against the ingress of energy from other sources and against electrical and magnetic fields.

8.4.1 Installation of cables and lines

When cables or lines are installed, they must be protected against mechanical damage, corrosion, chemical, and thermal effects.

This is a binding requirement in the intrinsic safety type of protection. The accumulation of an explosive atmosphere in shafts, channels, tubes, and gaps must be prevented. Combustible gases, vapors, liquids, and dusts must not be able to spread through them either. Wherever possible, cables or lines should not be interrupted when routed within a potentially explosive area. If this is not possible, the cables or lines must only be connected in a housing with a degree of protection that is approved for the zone. If this is not possible for installation reasons, the conditions set out in standard IEC/EN 60079-14 must be met.

The following also applies for intrinsically safe circuits, including those outside of the potentially explosive area:

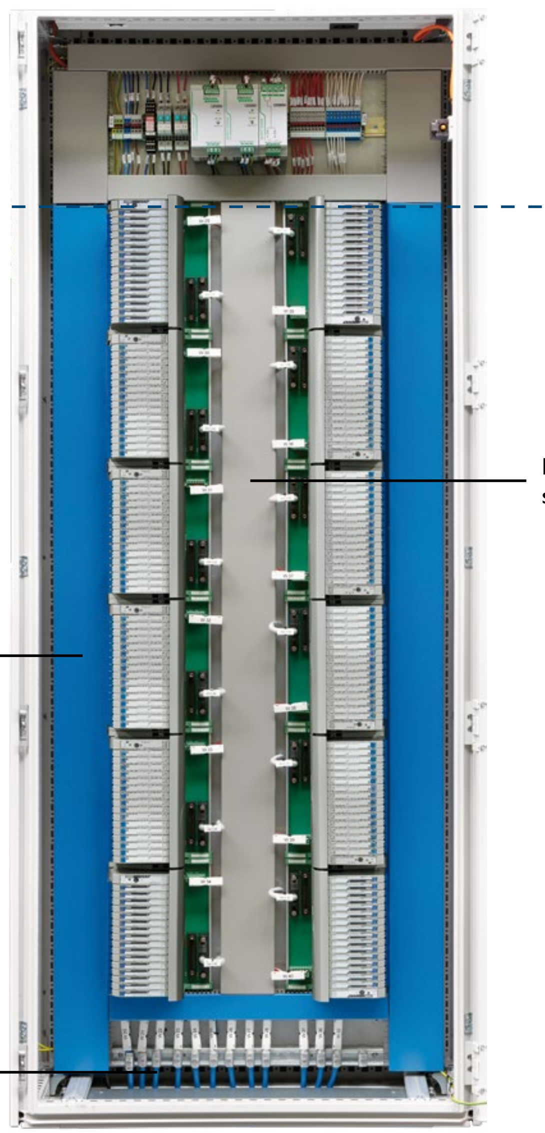
- Protection against the ingress of external energy
- Protection against external electrical or magnetic fields. Possible cause: high-voltage overhead line or single-phase high-voltage lines
- Single-core cables of intrinsically safe and non-intrinsically safe circuits must not be routed in the same cable
- Several intrinsically safe circuits can be routed in multi-strand cables or lines
- In the case of armored, metal-sheathed or shielded cables/lines, intrinsically safe and non-intrinsically safe circuits can be laid in one and the same cable duct
- Unused wires must be isolated from ground at both ends and isolated from other wires by suitable terminations.

Conductive shields may only be grounded at one point, which is usually located in the non-potentially explosive area. See also the section “Grounding in intrinsically safe circuits” (8.4.2).
In the control cabinet, the intrinsically safe circuits must be clearly marked. The standard does not stipulate a uniform process; rather, it simply indicates that a light blue color should preferably be used for marking. The neutral conductors of power cables are usually also marked by the color blue. In order to prevent any mix-up, different marking should be used for intrinsically safe circuits. A clear arrangement and spatial separation is advantageous in the control cabinet.

Selection criteria for cables/lines for intrinsic safety protection

Criterion	Condition	Note
Insulated cables/lines	Test voltage ≥500 V AC ≥750 V DC	Conductor ground, conductor shield, and shield ground
Diameter of individual conductors	≥0.1 mm	Also for fine-stranded conductors
Fine-stranded cables	Protect against splicing	e.g., with ferrules
Multi-strand cables/lines	Permitted	Take into account the fault monitoring conditions in IEC/EN 60079-14
Parameters	(C_c and L_c) or (C_c and L_c/R_c)	If in doubt: worst case

Distance between non-Ex i and Ex i



Non-intrinsically safe circuits in the safe area

Intrinsically safe circuits in potentially explosive areas

Light blue cable in Ex zone

Special cases for grounding conductive shields in intrinsically safe circuits

	Reason	Conditions
a	Shield has a high resistance; additional braided shield against inductive interference	Robust ground conductor (min. 4 mm^2), insulated ground conductor and shield: 500 V dielectric test, both grounded at one point, ground conductor meets the requirements of intrinsic safety and is specified on the certificate.
b	Equipotential bonding between both ends	Equipotential bonding across the entire area in which the intrinsically safe circuit is installed is ensured to a great extent.
c	Multiple grounding via small capacitors	Total capacitance is not above 10 nF.

8.4.2 Grounding in intrinsically safe circuits

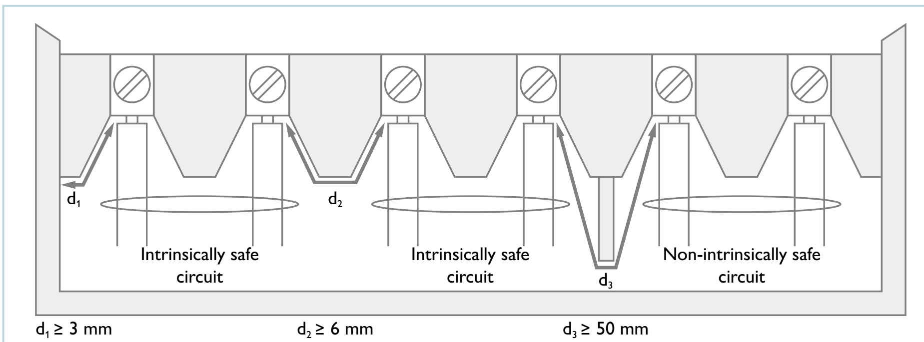
Potential differences can arise when intrinsically safe circuits are grounded. These must be taken into account when considering the circuits. Intrinsically safe circuits may be isolated from ground. The danger of electrostatic charge must be considered. Connecting via a resistor R = 0.2 … 1 MΩ in order to discharge the electrostatic charge does not count as a form of ground connection. An intrinsically safe circuit may be connected to the equipotential bonding system if this is only done at one point within the intrinsically safe circuit. If an intrinsically safe circuit consists of several electrically isolated sub-circuits, each section can be connected to ground once. If grounding is necessary for a sensor/actuator located in zone 0 due to its function, this must be implemented immediately outside of zone 0. Systems with Zener barriers must be grounded at these points. Mechanical protection against damage must also be provided if necessary. These circuits may not be grounded at another point. All electrical equipment that does not pass the voltage test with at least 500 V to ground is considered grounded. As for the electrical isolation of supply and signal circuits, the faults and transient currents in the equipotential bonding lines must be taken into account.

8.4.3 Clearances to connection terminal blocks

Between different intrinsically safe circuits
The clearance between terminal blocks in different intrinsically safe circuits must be at least 6 mm. The clearance between the conductive parts of the connection terminal blocks and conductive parts that can be grounded must be at least 3 mm. Intrinsically safe circuits must be clearly marked.

Between intrinsically safe and other circuits
The distance at terminal blocks between the conductive parts of intrinsically safe circuits and the conductive parts of non-intrinsically safe circuits must be at least 50 mm. The spacing can also be created using a partition plate made of insulating material or a grounded metal plate. Cables or conductors of intrinsically safe circuits must not come into contact with a non-intrinsically safe circuit, even if they should become loose from the terminal block of their own accord. The cables or conductors should be shortened accordingly during installation.

Special requirements in zone 0
Standard IEC/EN 60079-26, "Construction, test and marking of group II category 1 G electrical apparatus", has been added to the IEC/EN 60079 series. It describes further requirements for using equipment with types of protection other than intrinsic safety in zone 0.



Gaps in accordance with IEC/EN 60079-11

8.4.4 Maintenance and servicing

No special authorization (e.g., fire certificate) is required for the maintenance of intrinsically safe circuits. The cables of the intrinsically safe circuits can be short circuited or interrupted without endangering the type of protection. Intrinsically safe equipment can be replaced (or plug-in modules removed) without the system having to be switched off. Hazardous currents or voltages are not usually present in intrinsically safe circuits, so they are safe for people. Approved intrinsically safe measuring devices must be used to measure intrinsically safe circuits. Failure to take the data from these measuring devices into account could jeopardize the intrinsic safety.

8.5 Lightning and surge protection in intrinsically safe signal circuits

8.5.1 The hazard

The effects of overvoltages on signal circuits can jeopardize the availability of process engineering systems. These hazardous effects may be caused by switching operations in the power grid, electromagnetic interference from frequency converters, or even occur due to lightning strikes during stormy weather. In this case, it is important to consider that the lightning strike even represents a hazard if the distance to the system is a few kilometers. The electromagnetic field that is created during the charge equalization creates a situation where transient overvoltages are coupled into the signal lines by capacitive and inductive coupling, with the effect playing out at the ends of the cables. Moreover, local ground potential increases can arise, creating short-term differences in ground reference potential between the system parts. Components that are used in signal circuits requiring explosion protection must meet minimum insulation requirements. These items of equipment for the most part have a dielectric strength of 1.5 kV (signal wire to ground, common mode). The electric strength between the wires (differential mode), on the other hand, often only amounts to a few hundred volts or less. Cables must have a minimum dielectric strength of 500 V AC rms. In practice, however, the voltage spikes that can occur with lightning and overvoltage events are much higher. It is assumed that amplitudes of several kilovolts occur in just a few microseconds and the minimum insulation strength of the components in the signal circuit is exceeded. The larger the area of signal cables laid outdoors (called lightning protection zone 0), the greater the danger that the malfunctions in system parts or even destruction of electronic components can be caused by the effects described above.

8.5.2 Effective voltage limitation

Surge protection products effectively and permanently limit the voltage peaks in the signal network. In the normal operating state, the surge protection item has a very high impedance between the signal wires and the ground potential, as well as between the signal wires themselves, and therefore has no influence on the measuring circuits or data transmission. However, if the locally present voltage increases to impermissible values due to electromagnetic coupling or potential differences, the surge protection module becomes low-impedance within microseconds. Charging can be equalized via the modules. The voltage level at the electronic devices to be protected remains so limited during this process that the critical values are not exceeded. Once the charge equalization has taken place, the surge protection products return to the normal high-resistance operating state.

The surge protection must also be used on the premise that sparks cannot be created at an undefined position within the signal circuits and insulation materials. Therefore, surge protection also serves the purpose of secondary explosion protection with the aim of avoiding ignition sources in special situations where large short-term potential differences can occur.

The sparkover voltage of the protective devices is in some cases higher than the 500 V AC rms dielectric test voltage. In other cases, the sparkover voltage is somewhat lower, so as to protect both the terminal devices and the insulation on the cables and lines in such a case. What must be taken into consideration here is that the protective device or the surge protection plug must be removed from the installation in the event of insulation measurements. Signal circuits are often designed using an insulated two-wire approach with additional cable shielding. In addition to the two clamping surfaces for the signal wires, a third clamping surface on the protective device for the cable shielding can be used for direct grounding over the mounting rail. In addition, some SURGETRAB versions, for example, also offer the option of grounding the cable shielding indirectly via an additional gas-discharge arrestor. This option may make sense if unwanted currents are flowing over the cable shielding and it is grounded at both endpoints.

8.5.3 Various types of protection

A basic decision criterion for selecting a surge protective device for EX-protected areas is the type of protection and the associated approval. The Ex i type of protection is often found in the surge protection products, which are approved in accordance with ATEX and IECEx. Depending on the overall evaluation, the signal circuits can be routed to Ex zone 0. The surge protective devices are usually installed at the end points in the non-Ex area and in the Ex zones (up to zone 1).

For surge protection in intrinsically safe Ex circuits, IEC/EN 60079-14 specifies that 10 pulses of the form (8/20) µs must be able to be safely managed with a discharge surge current of 10 kA.

Another type of protection that is available is the increased safety Ex e. The use of such products is possible in Ex zone 2, taking certain conditions into consideration.

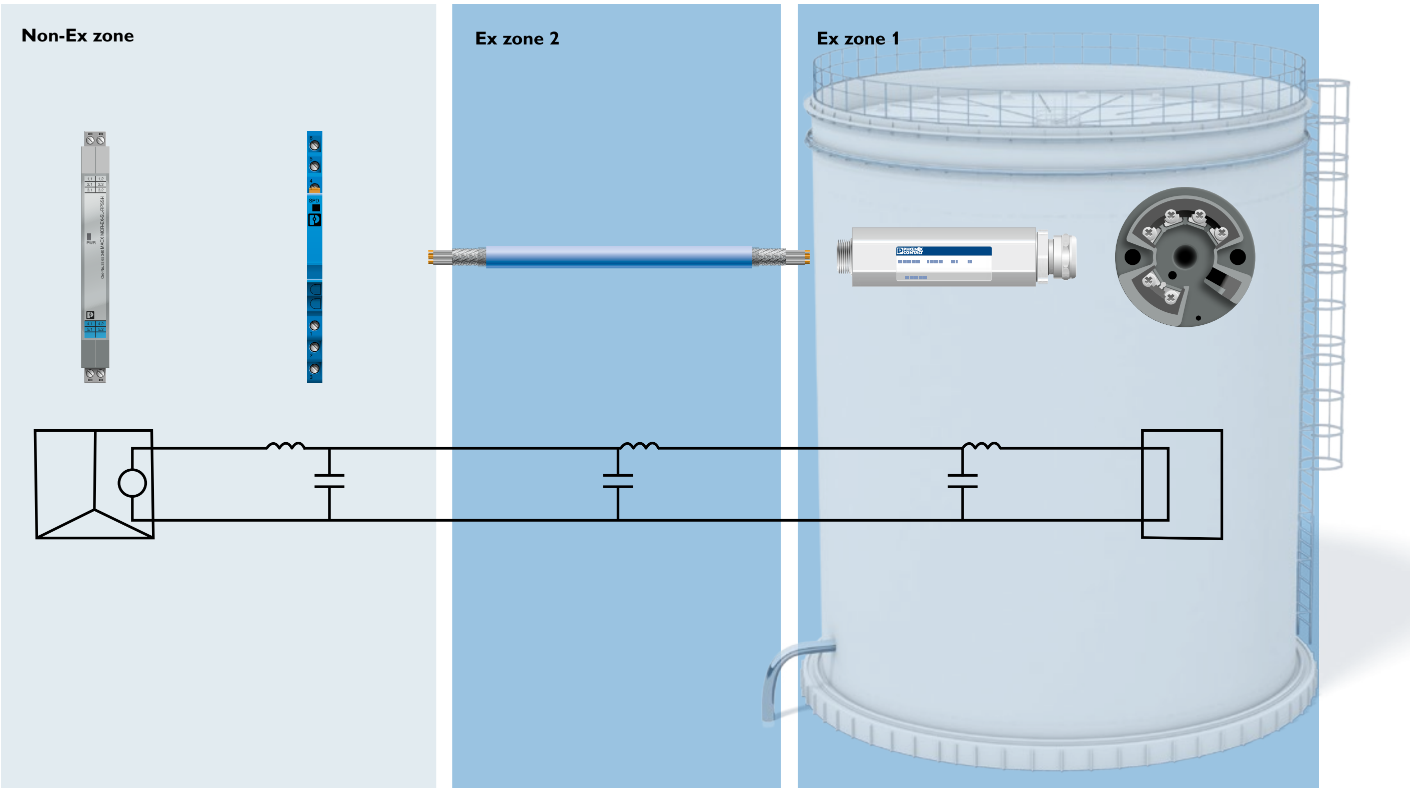
Some products that are installed directly on the field device also feature Ex d type of protection approval and, together with the field device, form an explosion-proof unit. This solution can be installed in Ex zone 1 or 2. Approvals in accordance with NEC/UL are also available for surge protection products and are certified and considered separately.

8.5.4 Proof of intrinsic safety

If surge protective devices are incorporated into the intrinsically safe circuit, then this must be taken into consideration when demonstrating intrinsic safety in accordance with IEC/EN 60079-25 Paragraph 13/ Appendix A. The data required for the calculation can be found in the ATEX/IEC certificate and the data sheets. Instances where individual parameters are not listed with an explicit value can be ignored. The following example illustrates how demonstration of proof might be carried out.

Example: Tank farm
A level measurement device on a fuel tank is connected to the control board via a long cable path of 500 m. Due to the explosive atmosphere that is always present inside the tank, Ex Zone 0 prevails there. The measurement values are converted to a unit current signal directly at the tank (4 to 20 mA) and then transmitted to the control board. This function unit is located in Ex zone 1. The SPD in the field is built directly on the measuring transducer. The distance of 1 m from Ex zone 0 should not be exceeded. The cables between the measuring sensor and the SPD must be designed so that they are protected against direct lightning interference. One possibility here would be to install the cables in a metal conduit. A significantly simpler approach is to use overvoltage protection items that can be mounted directly on the measuring head. An SPD is likewise deployed at the opposite end, so that the overvoltage is also effectively limited at the second cable end. See IEC/EN 60079-14 Paragraph 16.3 and other related materials for important contexts on the topic of surge protection in intrinsically safe circuits.

Parameter



Ex i signal isolators	Surge protection	Cables	Surge protection	Transmitters
MACX-MCR-EX-SL-RPSSI-I	TTC-6P-1X2-EX-24DC-UT-I		S-PT-EX(I)-24DC	FA MCR-EX-HT-TS-I-OLP-PT
U_o = 25.2 V DC	U_{i1} = 30 V DC		U_{i2} ≤ 30 V DC	U_{i3} ≤ 30 V DC
I_o = 93 mA	I_{i1} = 400 mA (TA<50°C @ T4)		I_{i2} ≤ 350 mA (TA<50°C)	I_{i3} ≤ 130 mA
P_o = 0.587 W	P_{i1} = --		P_{i2} = 3 W	P_{i3} = 800 mW
L_o = 2 mH	L_{i1} = negligible	L_C= 0.8 mH/km * 00 m = 0.4 mH	L_{i2} = 1 µH	L_{i3} = negligible
C_o = 107 nF	C_{i1} = negligible	C_C= 140 nF / km * 500 m = 70 nF	C_{i2} = 2 nF	C_{i3} = negligible

Verification

U_0 = 25.2 V ≤ U_{i1} = 30 V ✓	U_0 = 25.2 V ≤ U_{i2} = 30 V ✓	U_0 = 25.2 V ≤ U_{i3} = 30 V ✓
I_0 = 93 mA ≤ I_{i1} = 400 mA ✓	I_0 = 93 mA ≤ I_{i2} = 350 mA ✓	I_0 = 93 mA ≤ I_{i3} = 130 mA ✓
	P_0 = 587 mW ≤ P_{i2} = 3 W ✓	P_0 = 587 mW ≤ P_{i3} = 800 mW ✓
L_0 and C_0 can be fully utilized.		
L_0 = 2 mH ≥ L_{i1} + L_C + L_{i2} + L_{i3} = 0.4 mH + 1 µH = 0.4001 mH		
C_0 = 107 nF ≥ C_{i1} + C_{i2} + C_{i3} = 2 nF + 50 nF = 52 nF		

9 Connection technology in the Ex area

Connection technology plays an important role in the installation of signal and power supply cables in potentially explosive areas. This section provides an overview of the requirements for terminal blocks for intrinsically safe and non-intrinsically safe circuits and their installation in distributor boxes as well as cable entries in Ex d housings.

9.1 Terminal blocks for use in Ex e increased safety protection

Terminal blocks must meet the requirements for the connection of external conductors. The IEC/EN 60079-7 standard for increased safety forms the basis for the corresponding inspection.

As well as the type tests specified in the product standard, the additional requirements for increased safety can be summarized as follows:

- Sufficiently large air clearances and creepage distances
- Insulation materials that are resistant to temperature and aging
- Protection against accidental loosening
- Conductors must not be damaged during connection
- Continuous sufficient clamping pressure
- Contact reliability if temperature fluctuates
- No transmission of clamping pressure via the insulating material
- Multi-conductor connection only at suitable terminal points
- Elastic element for multi-stranded conductors of 4 mm² and up
- Specified torque for screw connection terminal blocks

The technical data for terminal blocks in the Ex area is specified by the type examination and documented on the certificate. The basic data for the use of terminal blocks and accessories is as follows:

- Rated insulation voltage
- Rated voltage
- Connectable conductor cross sections
- Operating temperature range
- Contact resistance in accordance with Section 8.2 of IEC/EN 60079-7

As approved components for the increased safety type of protection, terminal blocks are used in wiring spaces for devices for use in potentially explosive areas. The approval of components serves as the basis for certifying a device or protection system.

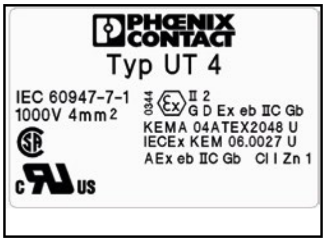
Feed-through terminal blocks and protective conductor terminal blocks with the “Ex eb” type of protection are used in Category 2 and EPL Gb devices for zones 1 and 2 for gases. The associated wiring spaces and housings must meet the requirements of the respective type of protection and be approved for it.

Terminal blocks for the type of protection “Ex ec” is evaluated or certified, may only be used in category 3 or EPL Gc devices for zone 2 (gases). In addition to feed-through terminal blocks, items such as suitable function terminals, that is, fuse terminal blocks or test disconnect terminal blocks can be used as Category 3 components in zone 2 in the “Ex ec” type of protection.

Approval of a component is indicated with the suffix “U”. Terminal blocks with increased safety “Ex e” type of protection must be appropriately marked.

Using the UT 4 feed-through terminal block as an example, the elements of the marking are shown on the side.

Rating plate



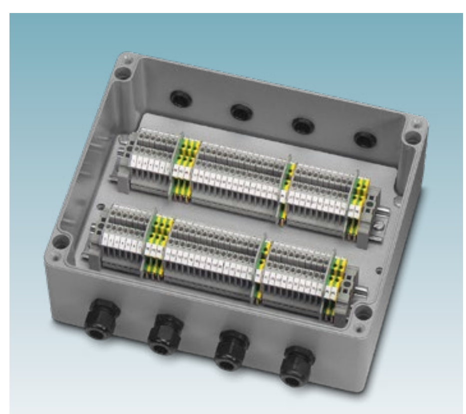
Marking requirements in accordance with IEC/EN 60079-0 for ATEX and IECEx	
Manufacturer's name or trademark	Potentially explosive area or
Type designation	UT 4
Marking for the type of protection	Ex eb IIC Gb
EU type examination certificate number in accordance with ATEX	KEMA 04ATEX2048 U
Certificate number in accordance with IECEx	IECEx KEM 07.0010 U

Packing label

Marking requirements in accordance with ATEX Directive 2014/34/EU, Appendix II	
Name and address of the manufacturer	Potentially explosive area 32825 Blomberg, Germany
Type designation	UT 4
Manufacturing date	2019-01-17
ID number of the notified body (DEKRA Certification B.V.)	0344
Type-tested in accordance with ATEX Directive 2014/34/EU	
Equipment group	II
Equipment category	2
Identification letter for gas explosion protection	G
Identification letter for dust explosion protection	D

Important notes:
Depending on their maximum operating temperature, terminal blocks can be used up to a temperature class of T6. Refer to the respective installation instructions for precise information on the operating temperature range, as well as regarding installation, use, and the use of accessories, if applicable.

Terminal block in Ex e



Terminal blocks in Ex e housing

9.2 Terminal blocks for Ex i intrinsic safety type of protection

In accordance with IEC/EN 60079-14, terminal blocks qualify as simple electrical equipment for use in intrinsically safe circuits. A type examination by a notified body and marking are not required. If terminal blocks are color coded as part of an intrinsically safe circuit, they must be light blue. This means that terminals that comply with the industry standard IEC/EN 60947-7-1 can be used directly in intrinsically safe circuits so long as the air clearance and creepage distances as well as the clearances provided by solid insulation are met in accordance with IEC/EN 60079-11.

The clearance between the external connections between two different intrinsically safe circuits must be at least 6 mm.

However, the minimum clearance between uninsulated connections and grounded metallic parts or other conductive parts need only be 3 mm.

These types of terminal blocks have been tested and generally satisfy the requirements of the intrinsic safety type of protection in accordance with IEC/EN 60079-0 and IEC/EN 60079-11, including the requirements on air clearances and creepage distances and clearances provided by solid insulation for circuits up to 60 V. A manufacturer's declaration is provided to demonstrate compliance.

To separate intrinsically safe and non-intrinsically safe circuits, a gap of least 50 mm must be created between the connection points.

Blue terminal housing for intrinsically safe circuits

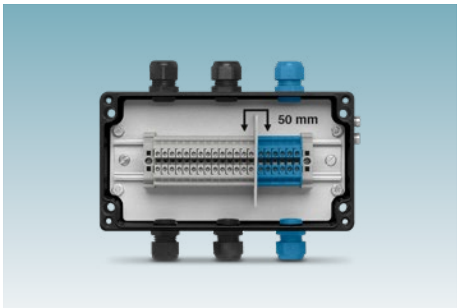
9.3 Ex e and Ex i circuits in a single housing

In electrical equipment, such as junction boxes, both intrinsically safe (Ex i) and increased safety (Ex e) circuits can be combined.

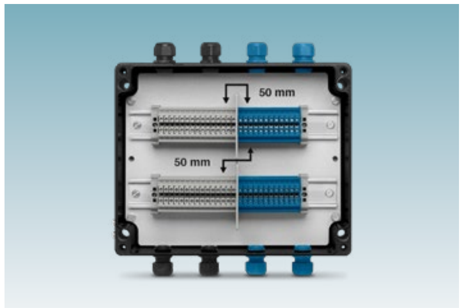
Safe mechanical isolation and, if necessary, visual separation are prescribed here. It must be ensured that individual conductors do not come into contact with conductive parts of the other circuits when the wiring is disconnected from the terminal block. The distance between the terminal blocks must be at least 50 mm.

Standard wiring procedures should also be observed so that it is unlikely that circuits will come into contact with one another even if a conductor becomes loose of its own accord. In control cabinets with a high wiring density, this separation is achieved by using either insulating or grounded metallic partition plates. Here too, the distance between intrinsically safe and non-intrinsically safe circuits must be 50 mm. Measurements are taken in all directions around the partition plate. The distance may be less if the partition plates come within at least 1.5 mm of the housing wall. Metallic partition plates must be grounded and must be sufficiently strong and rigid. They must be at least 0.45 mm thick.

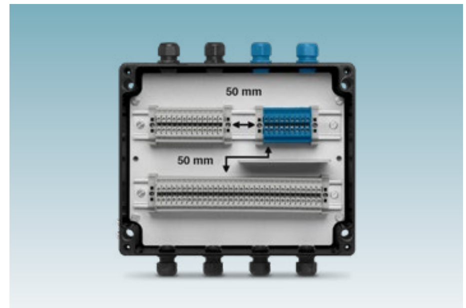
Non-metallic insulating partition plates must be at least 0.9 mm thick. The Ex e circuits must be additionally protected in the housing by a cover (at least IP30) if the end cover may be opened during operation. Otherwise, it is only permissible to open the end cover when the Ex e circuits are switched off. Corresponding warning labels must be attached.



Clearance through partition plate between intrinsically safe circuits and other circuits



Clearances between intrinsically safe circuits and other circuits must also be observed even when there are several DIN rails



Partition plate between DIN rail to ensure clearance

9.4 Housing entries

Two installation techniques are used worldwide:
In Europe, cable or line entries in the flameproof enclosure and increased safety types of protection are most commonly used. In the USA and Canada, the conduit system is traditionally used.

Cable or line entry
Cable or line entries are most frequently designed in increased safety Ex e protection or flameproof enclosure Ex d. Flameproof enclosure cable or line entries are dust ignition-proof and are used in conjunction with flameproof enclosure housings.

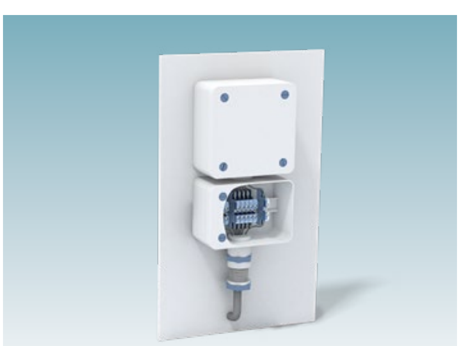
Increased safety cable or line entries are used in conjunction with housings in increased safety protection. The requirements regarding the IP protection of the housing must be taken into account when selecting the cable or line entry.

Conduit system
In the USA, particular importance is placed on providing the cables or lines with a high degree of mechanical protection, which is why the conduit system has become very widespread here.

Comparison of cable or line entry with conduit system
Compared to cables or lines or cable/line entries, conduit systems are more laborious to install.

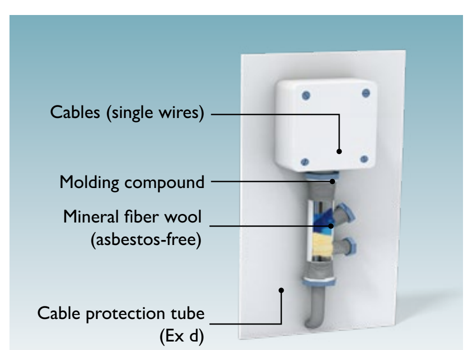
In addition, a conduit system could easily allow fuels, potentially explosive gas mixtures, or similar items to be transported unintentionally from one system part to the next. Preventing this requires additional blocking (sealing), for example, by molding individual segments of the conduit system.

Furthermore, condensation can easily form in conduit systems, which in turn can cause ground faults and short circuits as a result of corrosion.



Cable system with indirect entry (Ex e)

Cable system with direct entry (Ex d)



Conduit system with ignition lock (seal)

10 Installation of electrical devices for signal transmission in the Ex area

Electrical equipment operated in systems with Ex areas is subject to different usage requirements. For MCR technology, for example, the following applications may occur: (1) sensors and actuators are distributed in all Ex zones, (2) signal conditioners are located in zone 1, zone 2 or in the safe area, (3) the controller is generally in the safe area. The instrumentation can be done in accordance with intrinsic safety type and/or in a different type of protection.

10.1 Intrinsically safe signal transmission in potentially explosive areas

Sensors/actuators to be installed in zone 0 are primarily designed in intrinsic safety Ex ia protection. The intrinsically safe sensors/actuators are connected to the associated equipment with intrinsic safety Ex type of protection. The safety data required in order to dimension the intrinsically safe circuit is specified in the EU-type test certificate for the Ex i isolator.

If Ex i isolators are only approved in accordance with the intrinsic safety type of protection, they may only be installed outside of the potentially explosive area. If the Ex i isolators need to be installed inside the potentially explosive area, they must be installed in such a way that they are protected by a different type of protection, such as flameproof enclosure. If an Ex i isolator is mounted in flameproof enclosure housing, it can also be installed in zone 1. In addition to the intrinsic safety protection type, Ex i isolators can be designed and approved in accordance with another type of protection, for example, increased safety “ec” type of protection. If this is the case, they can be installed directly in zone 2, taking certain conditions into account.

The special installation conditions for installation in zone 2 are specified in the operating instructions of the Ex i isolator and include, for example, that a suitable and approved housing (IEC/EN 60079-15 and IEC/EN 60079-0) with at least IP54 protection class is used.

Ex i isolators that are approved in accordance with the Ex ia type of protection can also be used for sensors/actuators that are approved in accordance with the Ex ib or Ex ic type of protection.

10.2 Non-intrinsically safe signal transmission in potentially explosive areas

In addition to intrinsically safe signal transmission in potentially explosive areas, there are also sensors/actuators that are designed in other types of protection: for example, pressure-resistant enclosure Ex d or increased safety Ex e. For this purpose, the use of non-intrinsically safe isolators is permitted.

If non-intrinsically safe devices are to be installed in zone 2, the same requirements as previously described for the Ex i isolators apply. You need approval in accordance with Ex ec, which is accompanied by special conditions. The special installation conditions for installation in zone 2 are specified in the operating instructions of the isolator and include, for example, that a suitable and approved housing (IEC/EN 60079-15 and IEC/EN 60079-0) with at least IP54 protection class is used. If this approval is not granted, the isolators must be installed in a flameproof housing in accordance with Ex dc. However, this is usually significantly more expensive than an IP54 housing.

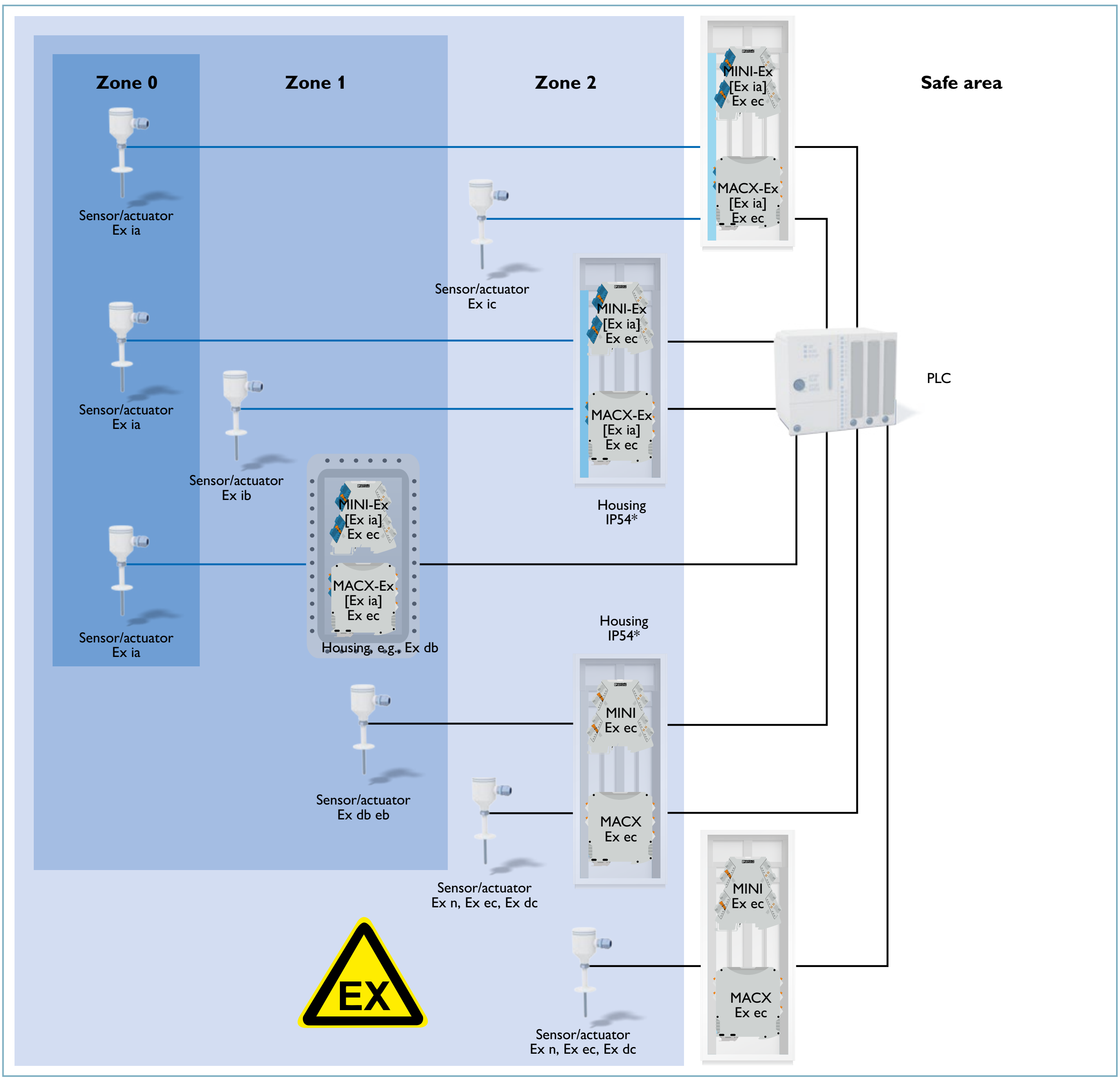
A sensor/actuator with type of protection “ec” can be connected to an intrinsically safe isolator or a non-intrinsically safe isolator in zone 2. If it is connected to an Ex i isolator, the intrinsic safety protection principle no longer has any effect. The Ex i isolator must be marked as a non-intrinsically safe isolator in order to ensure that it is no longer used in any intrinsically safe circuits.

When selecting suitable devices for zone 2, it must be ensured that the electrical data of the sensors/actuators is not exceeded. If the sensors/actuators are mounted in flameproof enclosure housing or if they have their own flameproof enclosure housing, they can also be installed in zone 1. The “ec” type of protection is also suitable if sensors/actuators are to be used in zone 2.

10.3 Installation requirements

The figure shows a range of options for installing electrical devices in areas with a danger of gas explosions. Special requirements regarding the configuration, selection, and installation of electrical systems in potentially explosive areas can be found in IEC/EN 60079-14. Other important factors when it comes to operating systems in potentially explosive areas are inspection, maintenance, and repairs. Specifications regarding these matters can be found in IEC/EN 60079-17 and IEC/EN 60079-19.

Example for the installation of electrical devices for signal transmission



11 Glossary

Potentially explosive area (abbreviation: Ex area)
An area in which a potentially explosive atmosphere is present or can be expected in such an amount that special precautionary measures are needed in the construction, installation, and use of electrical equipment.

Ex component
A part of electrical equipment for potentially explosive areas or a module (except for Ex cable/line entries) identified by the symbol U. Such a part may not be used by itself in such areas and requires an additional certificate when installed in electrical equipment or systems for use in potentially explosive areas.

U symbol
U is the symbol that is used after the certificate number to identify an Ex component.

X symbol
X is the symbol that is used after the certificate to identify special conditions for safe application.

Note: The symbols X and U are not used together.

Intrinsically safe circuit
A circuit in which neither a spark nor a thermal effect can cause the ignition of a particular explosive atmosphere.

Electrical equipment
The entire set of components, electric circuits or parts of electric circuits that are usually located within a single housing.

Intrinsically safe electrical equipment
An item of equipment in which all circuits are intrinsically safe.

Associated equipment
An item of electrical equipment that contains both intrinsically safe and non-intrinsically safe circuits and is designed in such a way that the non-intrinsically safe circuits cannot influence the intrinsically safe ones.

Note: This is also indicated by square brackets and round brackets in the marking. Associated equipment must be installed outside the potentially explosive area, provided that it does not comply with another suitable type of protection.

Simple electrical equipment
An item of electrical equipment or a combination of components with a simple design, with precisely determined electrical parameters, which does not impair the intrinsic safety of the circuit in which it is to be used.

Abbreviations:
Note: The index i denotes “in”, while o stands for “out”.

U_i = Maximum input voltage
The maximum voltage (peak value of the AC voltage or DC voltage) that can be applied to the connection elements of intrinsically safe circuits without affecting the intrinsic safety.
This means that no voltage higher than the value of the associated U_i may be connected to this intrinsically safe circuit.
A possible voltage addition must also be taken into consideration.
See also IEC/EN 60079-14, Appendix B.

I_i = Maximum input current
The maximum current (peak value of the alternating current or direct current) that can be supplied via the connection elements of the intrinsically safe circuits without destroying the intrinsic safety.

This means that no current higher than the value of the associated I_i may be fed into this intrinsically safe circuit.

A possible current addition must also be taken into consideration here.
See IEC/EN 60079-14, Appendix B here too.

P_i = Maximum input power
The maximum input power in an intrinsically safe circuit that can be implemented within electrical equipment without destroying the intrinsic safety.
This means that no intrinsically safe circuit with power higher than P_i may be connected here.

Note on U_i, I_i, and P_i:
The EU-type test certificate often only provides one or two specifications for U_i, I_i or P_i. In this case, there are no restrictions for the terms that are not mentioned, since a further, internal limitation has already been implemented in this item of equipment.

U_o = Maximum output voltage
The maximum output voltage (peak value of the AC voltage or DC voltage) in an intrinsically safe circuit that can occur under idling conditions at the connection elements of the electrical equipment with any applied voltage, up to the maximum voltage including U_m and U_i. This means that U_o is the maximum no-load voltage that can be present at the terminal blocks at the maximum supply voltage in the event of a fault.

I_o = Maximum output current
The maximum current (peak value of the alternating current or direct current) in an intrinsically safe circuit that can be taken from the connection terminal blocks of the electrical equipment.

This means that I_o corresponds to the maximum possible short-circuit current I_k at the connection terminal blocks.

P_o = Maximum output power
The maximum electrical power in an intrinsically safe circuit that can be taken from the equipment.

This means that when a sensor or actuator is connected to this intrinsically safe circuit, this power must be taken into consideration, for example, when heating up or with the load in relation to the associated temperature class.

C_i = Maximum internal capacitance
Effective equivalent capacitance for the internal capacitances of the equipment at the connection elements.

L_i = Maximum internal inductance
Effective equivalent inductance for the internal inductances of the equipment at the connection elements.

C_o = Maximum external capacitance
The maximum value of the capacitance in an intrinsically safe circuit that can be connected to the connection elements of the electrical equipment without destroying the intrinsic safety.

This means that this is the maximum value that all of the capacitances working outside of the equipment may attain. The external capacitances comprise the cable/line capacitances and the internal capacitances of the connected items of equipment. In the case of linear ohmic current limitation, C_o depends on U_o. See also IEC/EN 60079-11, Appendix A, Table A2 and Figure A2 and A3.

L_o = Maximum external inductance
The maximum value of the inductance in an intrinsically safe circuit that can be connected to the connection elements of the electrical equipment without destroying the intrinsic safety.

This means that this is the value that all of the inductances working outside of the equipment may attain in total. The external inductances comprise the cable/line inductances and the internal inductances of the connected items of equipment.

In the case of linear ohmic current limitation, L_o depends on I_o. See also IEC/EN 60079-11, Appendix A, Figure A4, A5, A6.

C_c = Cable or line capacity
Self-capacitance of a cable or line. This depends on the cable or line. It is generally between 140 nF/km and 200 nF/km.

L_c = Cable or line inductance
Self-inductance of a cable or line. This depends on the cable or line and is generally between 0.8 mH/km and 1 mH/km.

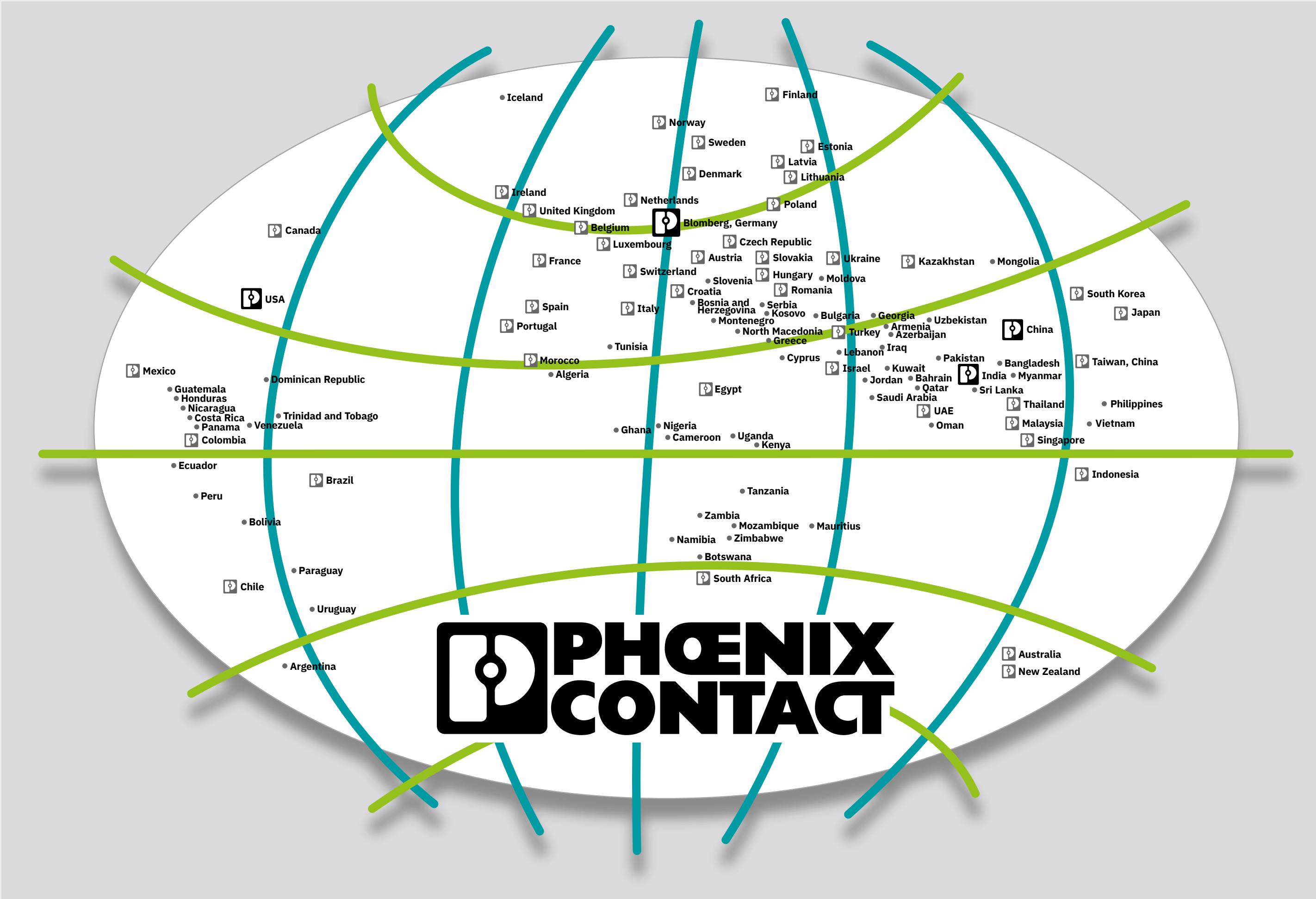
U_m = Maximum RMS value of the AC voltage or maximum DC voltage
The maximum voltage that can be connected to non-intrinsically safe connection elements of the associated equipment without affecting the intrinsic safety. The value of U_m can differ at the various connections of a device, as well as for AC and DC voltage.

This means that U_m = 250 V can be specified for the supply voltage and at the output U_m = 60 V, for example. In accordance with IEC/EN 60079-14, Clause 12.2.1 2, it must also be ensured that items of equipment that are connected to non-intrinsically safe connection terminal blocks of associated equipment are not supplied with a supply voltage that is higher than the U_m value specified on the rating plate of the associated equipment. For the above example, this means:

A further item of equipment with a supply voltage of up to 250 V can be connected to the supply voltage of the associated equipment. Only one item of equipment with a supply voltage of up to 60 V can be connected to the output of the associated equipment.

I_n = Rated fuse current
The rated current of a fuse in accordance with EN 60127 or in accordance with the manufacturer's specification. This is the nominal current that is specified for a fuse.

T_a or T_{amb} = Ambient temperature
The ambient temperature T_a or T_{amb} must be listed on the rating plate and specified on the certificate if it is outside the range of -20°C and +40°C.



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