Explosion protection

Theory and practice

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Explosion protection

This brochure on explosion protection is designed to provide installation technicians, planners, and operators of systems with potentially explosive atmospheres with an understanding of the particular risks involved and to help them carry out their day-to-day tasks. But not only in standard systems of the chemical and petrochemical industries does this issue have to be faced. Even in apparently harmless areas of the food industry, for example, there is a significant potential for danger. Explosion protection is often seen in connection with gases. However, explosive atmospheres can also be generated by dusts.

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You can find additional information about the products mentioned in this brochure in Phoenix Contact catalogs and online at **www.phoenixcontact.com**.

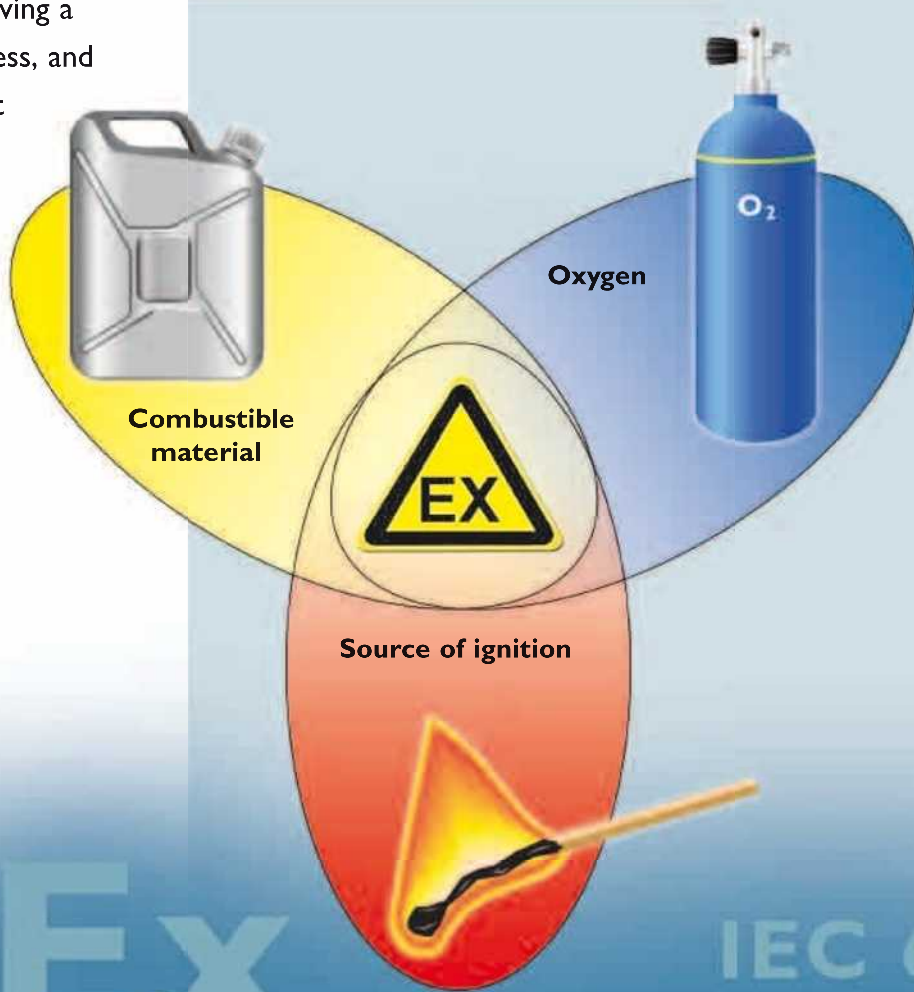
The first part of this brochure explains the basics of explosion protection in order to make you aware of the particular risks involved. Explosion protection around the world is mainly based on European and American standards and directives.

The second part provides support for the user of electrical equipment in potentially explosive areas. There is a clear explanation of which explosion protection criteria must be observed. In addition to MCR technology items of equipment for intrinsically safe circuits, you will also find information on modular terminal blocks and surge protection for potentially explosive areas.

The third part contains basic technical information concerning MCR technology and functional safety.

1 Principles of explosion protection

Ensuring the safety of people, achieving a safe and fault-free production process, and having a clean working environment are important aims. And the way to achieve these aims is to be aware of how explosions occur wherever combustible materials, oxygen, and sources of ignition can come together, and how to avoid them.



Creation of an explosion

Complete combustion

A complete combustion is a fast oxidation process. It is also referred to as a "destructive fire", a process in which a combustible material is decomposed exothermally where there is a sufficient supply of oxygen. As the speed with which the fire spreads increases, the process is referred to as deflagration, explosion and, in extreme cases, detonation, in this order. In the case of complete combustion, the damage caused increases significantly in proportion to the speed with which the fire spreads.

Magnitude of propagation velocity:

- Deflagration cm/s
- Explosion m/s
- Detonation km/s

Explosion

An explosion can occur if there is a combination of a combustible material, oxygen, and a source of ignition. If one component is missing, no exothermal reaction will occur.

Combustible material

A combustible material which is present as a gas, vapor or dust is called a potentially explosive material.

Vapors and dusts are potentially explosive if their droplet or particle size is smaller than 1 mm. Dusts with larger particle sizes are not usually flammable.

The vapors, aerosols, and dusts which occur in practice have a particle size of between 0.001 mm and 0.1 mm.

Oxygen

If a potentially explosive material is combined with oxygen, a potentially explosive atmosphere is created.

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
Arcs	Short circuit, switching operations
Hot surfaces	Heater, metal-cutting, heating up during operation
Flames and hot gases	Combustion reactions, flying sparks during welding
Electrical systems	Opening/closing of contacts, loose contact A PELV (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 anti-corrosion protection	Reverse currents from generators, short circuit to exposed conductive part/ground fault, induction
Electromagnetic waves in the range of $3 \times 10^{11} \ldots 3 \times 10^{15}$ Hz	Laser beam for distance measurement, especially for focusing
High frequency $10^{4} \ldots 3 \times 10^{12}$ Hz	Wireless signals, industrial high-frequency generators for heating, drying or cutting
Lightning strike	Atmospheric weather disturbances
Ionizing radiation	X-ray apparatus, 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
Exothermal reactions	Chemical reaction leads to heating up

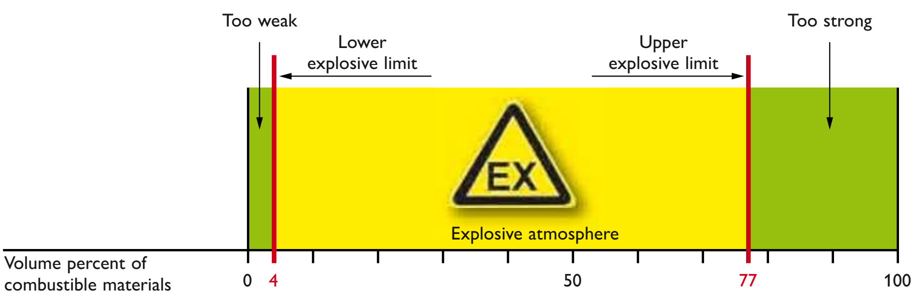
Upper and lower explosive limits

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 within the lower (LEL) and upper (UEL) explosive limits.

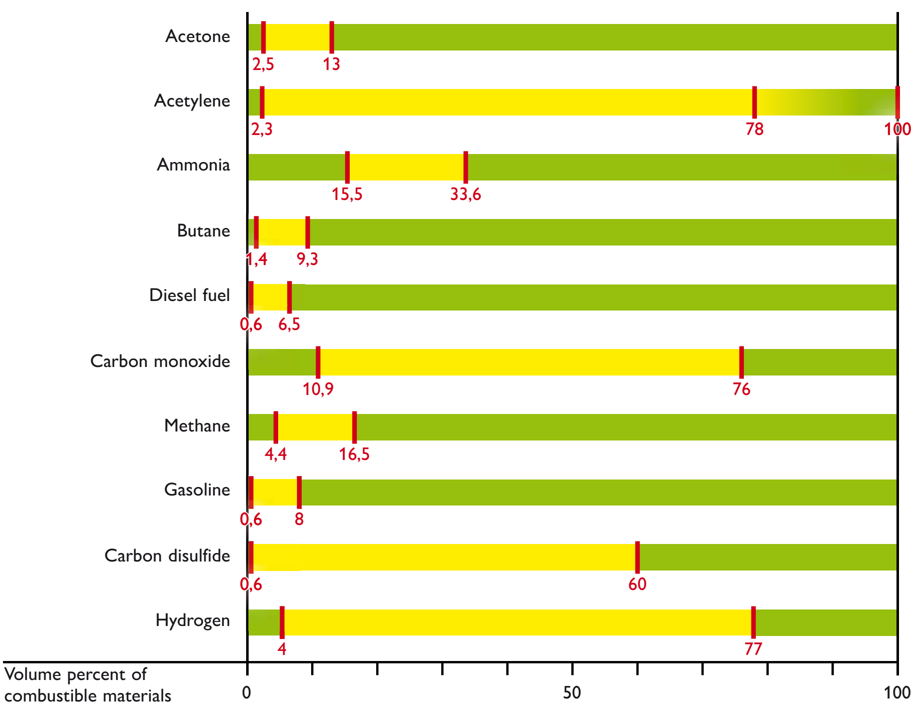
Some chemically non-resistant materials (e.g., acetylene, ethylene oxide) can also undergo exothermal reactions without oxygen by self-decomposition. The upper explosive limit (UEL) changes to 100 percent by volume. The explosive range of a material extends as the pressure and temperature rise.

Similar specifications can be made for dusts as for gases, even if the explosive limits do not have the same meaning here. Clouds of dust are generally inhomogeneous and the concentration within the same cloud will fluctuate sharply. A lower flammability limit (of approximately 20...60 g/m^3) and an upper flammability limit (of approximately 2...6 kg/m^3) can be determined for dusts.

Explosive limits of hydrogen



Examples of gases under normal pressure



1.1 Directives, standards, and regulations

Explosion protection in Europe

ATEX Directives

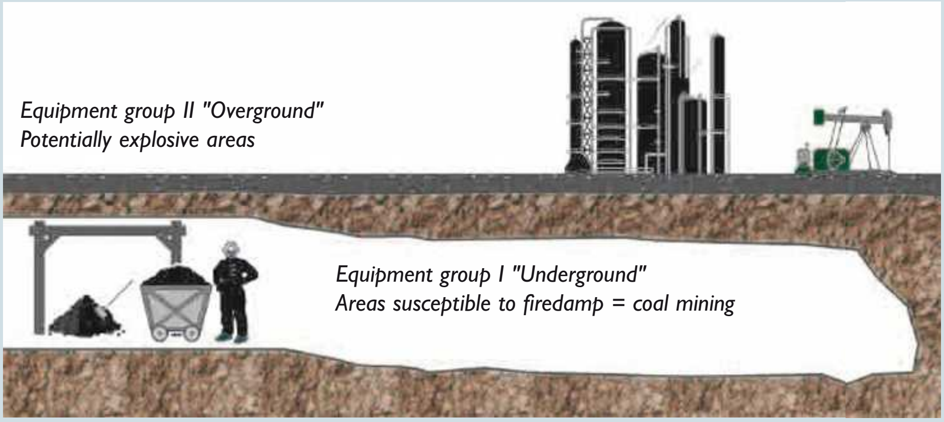
ATEX Directives define the free trade of goods within Europe. The term "ATEX" is derived from the French words "ATmosphère EXplosible".

In order to address the issue of explosion protection, the European Union introduced the ATEX Directive 94/9/EC for manufacturers and Directive 1999/92/EC for operators. These directives then had to be translated into the national legislation of the different member states.

Target group	Directive	Common designation*
Manufac-turer	94/9/EC	ATEX 100a ATEX 95
Operator	1999/92/EC	ATEX 118a ATEX 137

* *The directives are based on an article of the EU Treaty. The number of the article has changed.*

Equipment group and category according to ATEX Directive 94/9/EC



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 (see table on next page).

Equipment group I:

Devices for use in underground mining and the connected surface installations which are endangered by mine gases (methane) and/or combustible dusts.

Equipment group II:

Devices for use in all other areas which might be endangered by a potentially explosive atmosphere.

Categories are assigned to the equipment groups in Directive 94/9/EC. 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 the operator directive 1999/92/EC.

Requirements of equipment groups and categories				
Equip-ment group	Cate-gory	Degree of protection	Protection guarantee	Operating conditions
I	M1	Very high safety degree	Two independent protective measures. Safe if two faults occur independently of one another.	For reasons of safety, it must be possible to continue operating a product even if the atmosphere is potentially explosive.
I	M2	High safety degree	In normal operation, protective measures remain effective even in difficult conditions.	It must be possible to switch off these products if a potentially explosive atmosphere occurs.
II	1	Very high	Two independent protective measures. Safe if two faults occur independently of one another.	Devices can still be used in Zones 0, 1, 2 (G), and 20, 21, 22 (D) 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), and 21, 22 (D) and continue to be operated.
II	3	Normal	Safe in normal operation.	Devices can still be used in Zones 2 (G) and 22 (D) and continue to be operated.

Conformity assessment

The classification of electrical equipment according to equipment group and category is the basis for conformity assessment. The illustration shows this relationship. Except where Category 3 devices and individual testing are concerned, an EC-type examination is required for the conformity assessment.

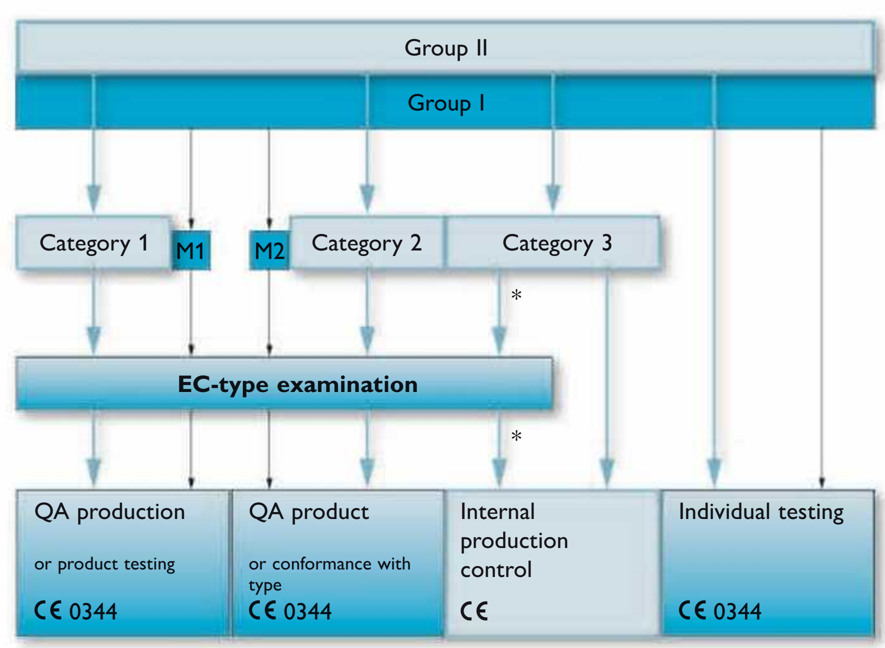
The modules are tested by a notified body.

Here is an example: CE 0344

CE: EC conformity for items of equipment. Components are not labeled with the CE mark.

0344: notified body, here: KEMA.

Category 3 – devices are not labeled with the number of a notified body, as they are not subject to production monitoring by said body.



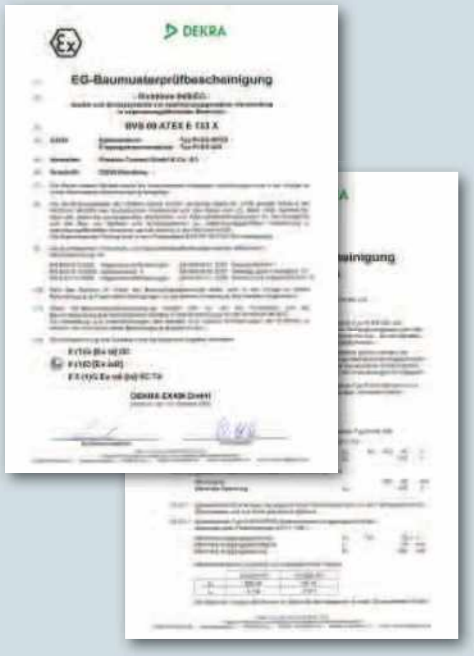
* *Possible as an option, similar procedure*

Conformity assessment according to Directive 94/9/EC for electrical equipment

Notified body according to 94/4/EC (extract)

The EC-type examination certificate confirms that the test has been carried out by a notified body. Notified bodies are determined by the EU.

Test center	Country	Identification
PTB	Germany	0102
DEKRA EXAM	Germany	0158
TÜV Nord	Germany	0044
IBExU	Germany	0637
ZELM Ex	Germany	0820
BAM	Germany	0589
SIRA	Great Britain	0518
INERIS	France	0080
LCIE	France	0081
LOM	Spain	0163
KEMA	The Netherlands	0344
CESI	Italy	0722
UL DEMKO	Denmark	0539
NEMKO	Norway	0470



Explosion protection in North America

Based on the North American Hazardous Location System (HazLoc), fundamental rules are determined for explosion protection.

The following institutions have been major players in developing the HazLoc system:

- Underwriters Laboratories Inc. (UL)
- CSA International (CSA)
- Factory Mutual Research (FM)
- Institute of Electrical and Electronics Engineers (IEEE)
- The Instrumentation, Systems and Automation Society (ISA)
- Mine Safety and Health Administration (MSHA)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- United States Coast Guard (USCG).

The basis for explosion protection in North America is the National Electrical Code (NEC) in the USA and the Canadian Electrical Code (CEC) in Canada. The listed excerpts of the NEC and CEC refer to explosion protection.

National Electrical Code (NEC) in the USA

Article	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 Zone 0, 1, and 2
506	General and special requirements for Zone 20, 21, and 22

Canadian Electrical Code (CEC) in Canada

Article	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
Annex J	General and special requirements for divisions of Class I

Standardization – Electrical explosion protection

Ensuring compliance with standards when developing devices enables manufacturers and, later, operators, to act with a certain degree of confidence. Different standards can be called on, depending on the area of application in question.

The ATEX Directive, for example, specifies compliance with basic health and safety requirements.

Manufacturers/operators can implement these requirements by means of harmonized standards or via an appropriate in-house concept.

The harmonized standards are published in the Official Journal of the European Union and their application goes hand in hand with a presumption of conformity. If the manufacturer chooses to use their own concept, comprehensive proof of conformity must be provided.

A Certificate of Conformity from IECEx can only be obtained if the corresponding IEC standards have been complied with.

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

Protection type	USA basis		Principle	EN standard	IEC standard	FM (USA)	UL (USA, div.)	UL (USA, zone)	CSA (Canada)
General regulations			Basis for protection types	EN 60079-0	IEC 60079-0	FM 3600 (ISA 12.00.01)			CSA E60079-0
Intrinsic safety	Ex i		Energy limitation	EN 60079-11	IEC 60079-11				
	AEx i	NEC505				FM 3610	UL 913	UL 60079-11	CSA E60079-11
	(IS)	NEC504				FM 3610			
Increased safety	Ex e		Constructional measures through spacing and dimensioning	EN 60079-7	IEC 60079-7				
	AEx e	NEC505				FM 3600 (ISA 12.16.01)	UL 2279 Pt.11	UL 60079-7	CSA E60079-7
Non-incendive	(NI)	NEC500	Constructional measures through spacing			FM 3611	ISA 12.12.01		C22.2 No. 213
Explosion-proof	(XP)	NEC500	Constructional measures through enclosure			FM 3615	E.g., housing: UL 1203		C22.2 No. 30
Flameproof enclosure	Ex d		Constructional measures through enclosure	EN 60079-1	IEC 60079-1				
	AEx d	NEC505				FM 3600 (ISA 12.22.01)	UL 2279 Pt.1	UL 60079-1	CSA E60079-1
Molded encapsulation	Ex m		Exclusion of a potentially explosive atmosphere	EN 60 079-18	IEC 60079-18				
	AEx m	NEC505				FM 3600 (ISA 12.23.01)	UL 2279 Pt.18	UL 60079-18	CSA E60079-18
Oil encapsulation	Ex o		Exclusion of a potentially explosive atmosphere	EN 60079-6	IEC 60079-6				
	AEx o	NEC505				FM 3600 (ISA 12.16.01)	UL 2279 Pt.6	UL 60079-6	CSA E60079-6
Sand encapsulation	Ex q		Exclusion of a potentially explosive atmosphere	EN 60079-5	IEC 60079-5	FM 3622			
	AEx q	NEC505				FM 3600 (ISA 12.25.01)	UL 2279 Pt.5	UL 60079-5	CSA E60079-5
Pressurization	Ex p		Exclusion of a potentially explosive atmosphere	EN 60079-2	IEC 60079-2				
	AEx p	NEC505				---	---	UL 60079-2	CSA E60079-2
	Type X, Y, Z	NEC500				FM 3620	NFPA 496		
Protection type "n"	Ex n		Improved industrial quality	EN 60079-15	IEC 60079-15				
	AEx n	NEC505				FM 3600 (ISA 12.12.02)	UL 2279 Pt.15	UL 60079-15	CSA E60079-15
Intrinsically safe electrical systems "i-Sys"	Ex i		Energy limitation in interconnected intrinsically safe circuits	EN 60079-25	IEC 60079-25				
Intrinsically safe fieldbus systems	Ex i		Energy limitation	EN 60079-27	IEC 60079-27				
Optical radiation	Ex op		Limitation of radiation power	EN 60079-28	IEC 60079-28				

Dust explosion protection in Europe

Just as there are standards regarding gas explosion protection, there are also standards for dust explosion protection.

Work is currently underway to merge these two sets of standards. This is possible because the 61241 series of standards for dust explosion protection and the 60079 series of standards for gas explosion protection both include protection types.

The 61421 series of standards has already been partially integrated into the 60079 series.

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

Protection type	USA basis	Principle	EN standard	IEC standard	FM (USA)	UL (USA, div.)	UL (USA, zone)	CSA (Canada)
General regulations		Basis for protection types	EN 60079-0	IEC 60079-0	FM 3600		ISA 61241-0	
Protection provided by housing	Ex t	Protection provided by housing design	EN 60079-31	IEC 60079-31			ISA 61241-1	
	(DIP) NEC500				FM 3616 FM 3611	UL 1203		
	(NI) NEC500				FM 3611			
Intrinsic safety	Ex i	Energy limitation	EN 61241-11	IEC 61241-11	FM 3610	UL 913	ISA 61241-11	
Pressurization	Ex p	Exclusion of a potentially explosive atmosphere	EN 61241-4	IEC 61241-4	FM 3620	NFPA 496	ISA 61241-4	
Molded encapsulation	Ex m	Exclusion of a potentially explosive atmosphere	EN 60079-18	IEC 60079-18			ISA 61241-18	

Abbreviations based on the NEC 500 in North America

XP	Explosion-protected
IS	Items of equipment with intrinsically safe circuits
AIS	Associated equipment with intrinsically safe circuits
ANI	Associated non-incendive field circuit
PX, PY, PZ	Pressurized enclosure
APX, APY, APZ	Associated pressurized system or component
NI	Non-incendive items of equipment and non-incendive field circuit
DIP	Dust ignition-proof

Standardization – Mechanical explosion protection

ATEX Directive 94/9/EC contains harmonized requirements for non-electrical devices, including in relation to use in areas with a danger of dust explosions.

There are standards for non-electrical devices, just as there are for electrical devices.

Standards for non-electrical equipment in potentially explosive areas

Protection type		EN standard
	Basic method and requirements	EN 13463-1
fr	Flow restricting enclosure	EN 13463-2 (for Equipment category 3 only)
d	Flameproof enclosure	EN 13643-3
c	Constructional safety	EN 13463-5
b	Control of ignition sources	EN 13463-6
p	Pressurization	EN 13463-7
k	Liquid immersion	EN 13463-8

Standardization – Planning, installation, and operation

Directive 1999/92/EC requires operators of process engineering systems to ensure that those systems are protected against explosion. The requirements which must be met in this regard are specified in EN and IEC standards.

Designation	EN standard	IEC standard
Explosion prevention and protection Part 1: Basic concepts and methodology	EN 1127-1	
Electrical apparatus for explosive gas atmospheres Part 10: Classification of hazardous areas	EN 60079-10 New: EN 60079-10-1	IEC 60079-10 New: IEC 60079-10-1
Electrical apparatus for explosive gas atmospheres Part 14: Electrical installations in hazardous areas (other than mines)	EN 60079-14	IEC 60079-14
Electrical apparatus for explosive gas atmospheres Part 17: Inspection and maintenance of electrical installations in hazardous areas (other than mines)	EN 60079-17	IEC 60079-17
Explosive atmospheres Part 19: Equipment repair, overhaul and reclamation	EN 60079-19	IEC 60079-19
Electrical apparatus for use in the presence of combustible dust Part 10: Classification of areas where combustible dusts are or may be present	EN 61241-10 New: EN 60079-10-2	IEC 61241-10 New: IEC 60079-10-2
Electrical apparatus for use in the presence of combustible dust Part 14: Selection and installation	EN 61241-14	IEC 60079-14
Electrical apparatus for use in the presence of combustible dust Part 17: Inspection and maintenance of electrical installations in hazardous areas (other than mines)	EN 61241-17	IEC 61241-17

1.2 Zone classification

Europe

Potentially explosive areas are allocated to standard zones that are distinguished according to two types:

- Areas with a danger of gas explosions and
- Areas with a danger of dust explosions.

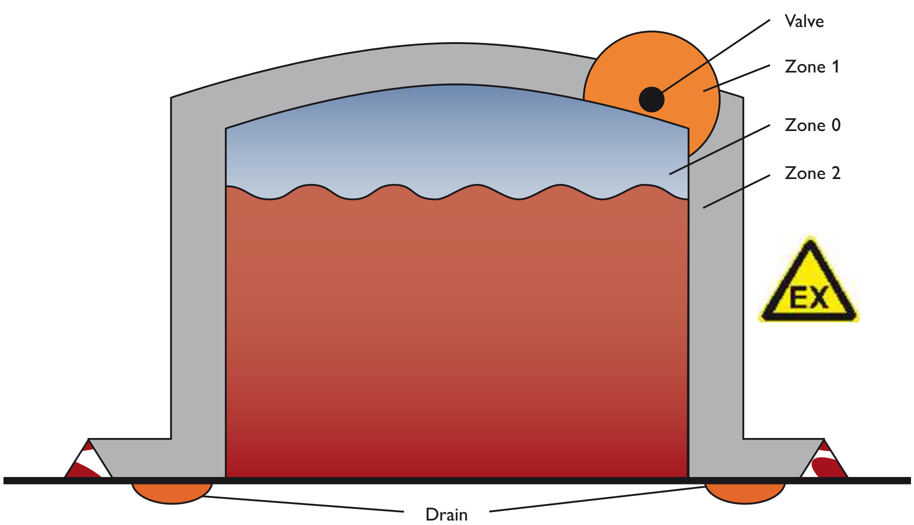
Previously, zones for gases were defined in EN 60079-10 and for dusts in EN 61241-10.

In transferring the series of dust-related standards EN 61241 into the series of standards EN 60079, the classification into areas with a danger of gas explosions and those with a danger of dust explosions was maintained in EN 60079-10 Part 10-1 and Part 10-2.

The European Committee for Standardization (CEN) also created standard EN 1127-1. EN 1127-1 contains basic information about explosion protection and provides support for both ATEX Directives (94/9/EC and 1999/92/EC).

The zones are classified based on the frequency of the occurrence of potentially explosive atmospheres. The explosion protection rules of the German Trade Association for Chemicals (Berufsgenossenschaft Chemie) contain additional support and advice in terms of zone classification.

Example of zone classification



Zones for areas with a danger of gas explosions

Zones for areas with a danger of gas explosions are defined in EN 60079-10-1.

Zones	Type of danger
Zone 0	Continuous, long periods, frequent
Zone 1	Occasional
Zone 2	Not usually present, short periods only

Zones for areas with a danger of dust explosions

Zones for areas with a danger of dust explosions* were defined for the first time in EN 61242-10. Today they can be found in EN 60079-10-2.

Classification in Germany prior to ATEX	Classification according to ATEX	Type of danger
Zone 10	Zone 20	Continuous, long periods, frequent
	Zone 21	Occasional
Zone 11	Zone 22	Not usually present, short periods only

** General assignment, individual cases must be checked*

In Germany, dusts were previously divided into two zones. When standards were revised as a result of European directives, dusts were also divided into three zones (in line with the classification of gases into three zones) throughout Europe. However, it must be taken into account that Zones 10 and 11 cannot be transferred to the new zone classifications automatically, without being checked.

Relationship between zones and categories

The relationship between the zones and equipment categories is laid down in Annex 2 of operator directive 1999/92/EC.

Assignment in acc. with 1999/92/EC

Zone	Equipment category
0, 20	1
1, 21	1, 2
2, 22	1, 2, 3

North America

In the USA, zones or divisions are divided up according to the National Electrical Code (NEC). In Canada the procedure is similar, but following the Canadian Electrical Code (CEC). The comparison with the IEC/EN zone classification can only be regarded as a general approximation.

The conversion must be checked in individual cases. This applies in particular to electrical equipment for Division 2, which can often only be used in this zone with additional testing and certification. The possibilities are shown in the simplified assignment diagram.

Potentially explosive areas with typical materials

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

Simplified assignment diagram for zones and divisions

	Areas					
IEC/EN	Zone 0	Zone 1		Zone 2		
USA: NEC 505	Zone 0	Zone 1		Zone 2		
USA: NEC 500	Division 1			Division 2		
	Potentially explosive material	Class	Group	Potentially 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	—

Meanings of classes, divisions, and zones		
Classification	Potentially explosive atmosphere	Type of danger
Class I, Division 1	Gas, liquid, and vapor	Incendive 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	Incendive concentrations of inflammable gases, vapors or liquids do not usually occur under normal operating conditions.
Class I, Zone 0	Gas, liquid, and vapor	Incendive concentrations of inflammable gases, vapors or liquids occur constantly or for long periods of time under normal operating conditions.
Class I, Zone 1	Gas, liquid, and vapor	Incendive concentrations of inflammable gases, vapors or liquids usually occur under normal operating conditions.
Class I, Zone 2	Gas, liquid, and vapor	Incendive concentrations of inflammable gases, vapors or liquids do not usually occur under normal operating conditions.
Class II, Division 1	Dust	Incendive concentrations of combustible dust may be present constantly or temporarily under normal operating conditions.
Class II, Division 2	Dust	Incendive 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.

1.3 Protection types

General requirements

The basis for the standardized protection types are the requirements for the surface temperature, the air and creepage distances, the labeling of electrical equipment, the assignment of electrical equipment to the area of application, and the zones.

Everything that goes beyond the basic necessary and generally valid requirements is specified in the respective protection type.

Classification of devices into groups

The ATEX Directive requires that devices are classified into groups. Underground mining is assigned Equipment group I. This group was previously identified by the term "susceptible to firedamp" (old German abbreviation: "Sch").

All other potentially explosive areas are assigned to Equipment group II. Examples include the petrochemicals industry, chemicals industry, and silo plants where combustible dusts are present. This group was previously identified by the term "potentially explosive" (old abbreviation: "Ex").

Devices not only belong to equipment groups according to the ATEX Directive, they are also assigned to another group as per their subsequent field of application in accordance with the 60079 series of standards.

In the "intrinsic safety", "flameproof enclosure", and "n" protection types, devices were also classified into Group IIA, IIB or IIC for gases.

Maximum permissible energy according to EN 60079-11

Group	Maximum permissible energy
IIC	20 µJ
IIB	80 µJ
IIA	160 µJ

The new EN 60079-0:2009 standard no longer distinguishes between the protection types: All devices must be assigned to Group IIA, IIB or IIC. A third group has also been introduced in EN 60079-0:2009. Group III describes combustible dusts and is further subdivided into IIIA, IIIB, and IIIC.

<table>
<tr><th>Areas</th><th>Equipment group according to Directive 94/9/EC</th><th colspan="2">Group according to EN 60079-0:2006</th><th colspan="2">Group according to EN 60079-0:2009</th></tr>
<tr><td>Mines susceptible to firedamp</td><td>Group I</td><td colspan="2">Group I</td><td colspan="2">Group I</td></tr>
<tr><td>Areas with a danger of gas explosions</td><td>Group II</td><td rowspan="2">Group II**</td><td rowspan="2">IIA
IIB
IIC</td><td>Group II</td><td>IIA
IIB
IIC</td></tr>
<tr><td>Areas with a danger of dust explosions</td><td>Group II</td><td>Group III*</td><td>IIIA
IIIB
IIIC</td></tr>
</table>

* *IIIA: combustible flyings, IIIB: non-conductive dust, IIIC: conductive dust*
** *According to the protection type*

Temperature classes/limits for gases and dusts

Temperatures for Group I

The maximum permissible surface temperature of the item of equipment depends on the type of coal dust deposit.

Temperatures for Group I

Group I	Temperature	Conditions
Mines susceptible to fire-damp (coal mining)	150°C	With deposits of coal dust on the item of equipment
	450°C	Without deposits of coal dust on the item of equipment

Temperature classes for Group II

The potentially explosive atmosphere can be prevented from igniting if the surface temperature of the item of 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 potentially explosive material.

The majority of the gases can be assigned to the temperature classes T1 to T3.

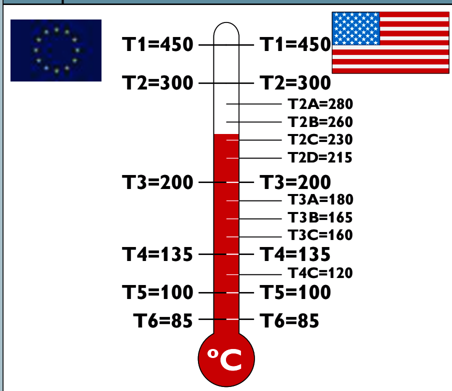
Permissible surface temperature for gases

Ignition temperature of the gas	
Ammonia	630°C
Methane	595°C
Hydrogen	560°C
Propane	470°C
Ethylene	425°C
Butane	365°C
Acetylene	305°C
Cyclohexane	259°C
Diethyl ether	170°C
Carbon disulfide	95°C

Reference: GESTIS Substance Database

Group II temperature classes for Europe and the USA

Group II



Example

Modular terminal blocks are used in a housing of protection type Ex e IIC T6.

In this case, the maximum permissible amperage must be calculated so that the temperature class T6 is also maintained at the modular terminal blocks. The housing is designed with IP degree of protection IP54, but the potentially explosive gas can still penetrate the housing. For this reason, it is not sufficient only to consider the surface temperature of the housing.

Housing Ex e with modular terminal blocks

Temperature limits with dust

In the case of areas with a danger of dust explosions, the maximum surface temperature is given as a temperature value [°C].

The maximum surface temperature of the item of equipment must not exceed the ignition temperature of a layer of dust or a cloud of combustible dust.

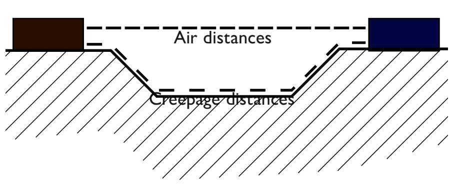
Air and creepage distance

Air and creepage distances must be maintained for the "intrinsic safety", "increased safety", and "n" protection types.

The term "air distance" is defined as the shortest connection between two potentials through the air. The "creepage distance" is the shortest connection between two potentials over a surface.

A minimum distance must be maintained, depending on the comparative tracking index (CTI) of the material.

The minimum air and creepage distances to be applied are specified in the corresponding protection type.



Air and creepage distance

Protection types and their application

Protection types for electrical equipment in areas with a danger of gas explosions					
Protection type		Protection principle	EN/IEC	Zone	Application
d	Flameproof enclosure	Prevention of an explosion from spreading	EN 60079-1 IEC 60079-1	1 or 2	Switching, command, and signaling devices, controllers, motors, power electronics
px, py, pz	Pressurization	Exclusion of a potentially explosive atmosphere	EN 60079-2 IEC 60079-2	1 or 2	Control cabinets, motors, measuring and analysis devices, computers
q	Sand encapsulation	Prevention of sparks	EN 60079-5 IEC 60079-5	1 or 2	Transformers, relays, capacitors
o	Oil encapsulation	Exclusion of a potentially explosive atmosphere	EN 60079-6 IEC 60079-6	1 or 2	Transformers, relays, startup controllers, switching devices
e	Increased safety	Prevention of sparks	EN 60079-7 IEC 60079-7	1 or 2	Branch and connection boxes, housings, motors, terminal blocks
ia, ib, ic	Intrinsic safety	Limitation of the ignition energy	EN 60079-11 IEC 60079-11	0, 1 or 2	MCR technology, sensors, actuators, instrumentation
	Intrinsically safe systems		EN 60079-25 IEC 60079-25	0, 1 or 2	
	Intrinsically safe fieldbus systems (FISCO), non-sparking fieldbus systems (FNICO)		EN 60079-27 IEC 60079-27	1 or 2	
nA	Non-sparking item of equipment	Comparable with Ex e	EN 60079-15 IEC 60079-15	2	Zone 2 only
nC	Sparking item of equipment	Comparable with Ex d	EN 60079-15 IEC 60079-15	2	Zone 2 only
nL*	Energy limited * Different in North America and Europe, in future "ic"	Comparable with Ex i	EN 60079-15 IEC 60079-15	2	Zone 2 only
nR	Restricted breathing housing	Protection provided by housing	EN 60079-15 IEC 60079-15	2	Zone 2 only
nP	Simplified pressurization	Comparable with Ex p	EN 60079-15 IEC 60079-15	2	Zone 2 only
ma, mb, mc	Molded encapsulation	Exclusion of a potentially explosive atmosphere	EN 60079-18 IEC 60079-18	0, 1 or 2	Coils of relays and motors, electronics, solenoid valves, connection systems
op is, op pr, op sh	Optical radiation	Limiting or avoiding the transmission of energy from optical radiation	EN 60079-28 IEC 60079-28	1 or 2	Optoelectronic devices

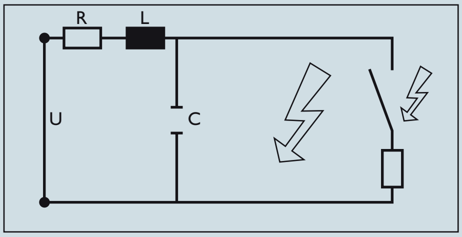
Protection types for electrical equipment in areas with combustible dust					
Protection type		Protection principle	EN/IEC	Zone	Application
tD New: ta, tb, tc	Protection provided by housing	Exclusion of a potentially explosive atmosphere	EN 61241-1 IEC 61241-1 New: EN 60079-31 IEC 60079-31	21 or 22	Switching, command, and signaling devices, lamps, branch and connection boxes, housings
pD In future: p	Pressurization	Exclusion of a potentially explosive atmosphere	EN 61241-4 IEC 61241-4 In future: EN 60079-2 IEC 60079-2	21 or 22	Control cabinets, motors, measuring and analysis devices
iaD, ibD In future: ia, ib, ic	Intrinsic safety	Limitation of the ignition energy and surface temperature	EN 61241-11 IEC 61241-11 In future: EN 60079-11 IEC 60079-11	20, 21 or 22	MCR technology, sensors, actuators, instrumentation
maD, mbD New: ma, mb, mc	Molded encapsulation	Exclusion of a potentially explosive atmosphere	EN 61241-18 IEC 61241-18 New: EN 60079-18 IEC 60079-18	20, 21 or 22	Coils and relays of the motors, electronics and connection systems

The requirements of the EN and IEC standards are going to be transferred into the corresponding standards for items of equipment in areas with a danger of gas explosions; this work has already been completed for some standards.

Intrinsic safety Ex i

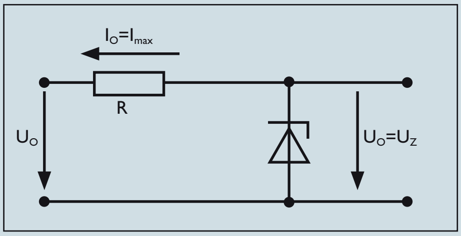
Principle

The "intrinsic safety" protection type, as opposed to other protection types (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.



Basic 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, i.e., excessively hot surfaces, is prevented by limiting the current. This is also true of the sensors connected to the intrinsically safe circuits. Energy may be stored in the form of capacitances or inductances within the intrinsically safe circuit and this must also be taken into account when examining said circuit.



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 laid down in standard EN 60079-11.

The ignition limit curves were determined using a spark tester, as described in Annex B of EN 60079-11.

The ignition limit curves contain specifications for gas groups I and II.

Group II is further subdivided into IIA, IIB, and IIC, depending on the ignition energy.

Ignition energies of typical gases

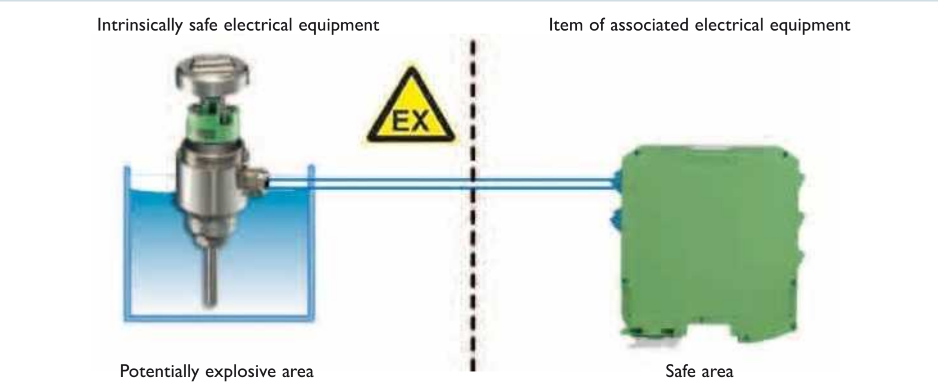
Group	Typical gas	Ignition energy/µJ
I	Methane	280
II A	Propane	> 180
II B	Ethylene	60 … 180
II C	Hydrogen	< 60

Electrical equipment and items of associated electrical equipment

An intrinsically safe circuit consists of at least one item of electrical equipment and one item of associated equipment.

The circuits of the electrical equipment fulfill the requirements of intrinsic safety. Electrical equipment may only be connected to circuits without intrinsic safety via associated equipment. Associated equipment has both intrinsically safe circuits and circuits without intrinsic safety. The circuits are isolated using Zener barriers or electrical isolators.

Intrinsically safe electrical equipment and intrinsically safe parts of associated equipment are classed according to EN 60079-11 in safety levels "ia", "ib", and "ic".



Example: Interconnection of electrical equipment in the "intrinsic safety" protection type

Safety level according to EN 60079-11

Safety level	Fault monitoring	Permis-sible 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

Safety level "ia", "ib" or "ic" defines whether protection is maintained with two or one faults in the protective circuit, or whether no protection is provided in the event of a fault.

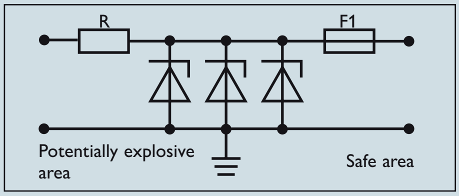
Intrinsic safety is based on monitoring faults in order to rule out the danger of explosion. This does not, however, provide any conclusions as to operational reliability. This means that a total functional failure of the item of equipment can be permissible from the point of view of explosion protection.

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, according to the safety level.

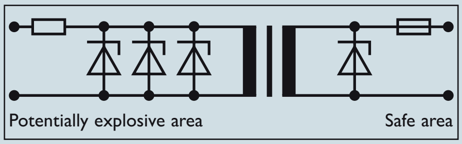
Associated equipment can always be designed in a different protection type in order for it to be installed in Zone 2 or maybe even in Zone 1.

Associated equipment with/without electrical isolation

For intrinsically safe circuits in Zone 0, standard EN 60079-14, Section 12.3 recommends that electrical isolation should be preferred, along with the "ia" safety level.



Without electrical isolation: Zener barrier



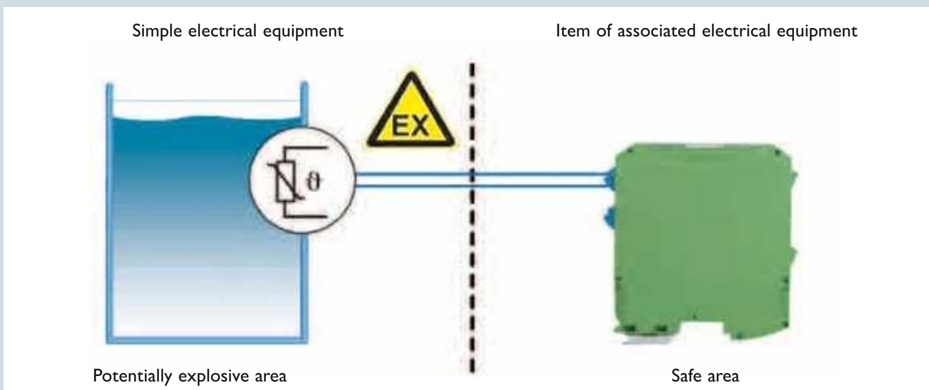
With electrical isolation: Isolator

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 EN 60 079-11.

The maximum temperature can be calculated from power Po of the associated equipment and the temperature class can then be determined.

The characteristics of the power storage device must be specified precisely and must be taken into account when determining the overall safety of the system.



Overview of simple electrical equipment (EN 60079-11)

Passive components	Power storage device	Power sources*
Pt100	Capacitor	Thermocouple
Switch	Coil	Photo cells
Distributor boxes		* Requirement U ≤ 1.5 V I ≤ 100 mA P ≤ 25 mW
Resistors		

Protection type "n"

Protection type "n" can be described as an improved industrial quality that is designed for normal operation. A fault scenario examination as is performed for the "intrinsic safety" protection type, for example, is not carried out.

This can only be applied for Equipment group II and the use of electrical equipment in Zone 2. The manufacturer specifies the technical data for normal operation. In protection type "n", five different versions are distinguished, which can be derived in part from the well-known protection types "increased safety", "intrinsic safety", "flameproof enclosure", "pressurization", and "molded encapsulation".

This protection type was developed based on the US "non-incendive" (NI) protection type and was introduced in Europe as a standard in 1999.

Here it is further divided into the subgroups nA, nC, nR, nL, and nP.

The protection type nL will not be included in the next revision of EN 60079-15. It will be transferred to standard EN 60079-11, as safety level "ic".

Subdivision of protection type "n" in Europe

Abbreviation	Meaning	Comparable to ...	Method	Subdivisions of Group II
A	Non-sparking	Ex e	Occurrence of arcs, sparks or hot surfaces is minimized	As of EN 60079-0:2009, subdivided into IIA, IIB, IIC
C	Sparking items of equipment	To some extent, Ex d and Ex m	Enclosed switching device, non-incendive components, hermetically sealed, sealed or encapsulated installations	IIA, IIB, IIC
R	Restricted breathing housing	---	Ingress of explosive gases is limited	As of EN 60079-0:2009, subdivided into IIA, IIB, IIC
L *	Energy limited	Ex i	Energy limitation so that neither sparks nor thermal effects cause an ignition	IIA, IIB, IIC
P	Simplified pressurization	Ex p	Ingress of explosive gases is prevented by overpressure, monitoring without disconnection	As of EN 60079-0:2009, subdivided into IIA, IIB, IIC

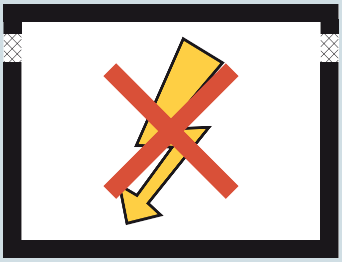
** Different in North America and Europe*

Subdivision of protection type "n" in North America

Designation according to NEC	Meaning
Energy limited "nC" *	Energy limited
Hermetically sealed "nC"	Hermetically sealed
Non-incendive "nC"	Non-incendive items of equipment
Non-sparking "nA"	Non-sparking items of equipment
Restricted breathing "nR"	Restricted breathing
Sealed device "nC"	Sealed items of equipment
Simplified pressurization "nP" **	Simple pressurization

** Different in North America and Europe*
*** Designated as type X, Y, and Z in the USA*

Increased safety Ex e



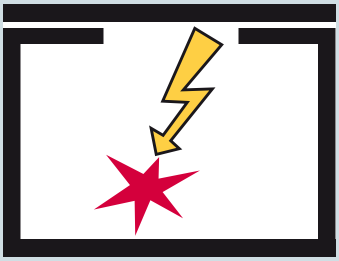
In the "increased safety" protection type, voltages up to 11 kV can be brought into the potentially explosive area. Increased safety is especially suitable for supplying motors, lamps, and transformers.

The protection principle is based on constructional measures.

Air and creepage distances are determined for the live parts, divided into voltage levels. This prevents electrical sparks. In addition, IP degree of protection (EN 60529) IP54 must be fulfilled as a minimum.

Limiting the surface temperature ensures that the potentially explosive atmosphere cannot be ignited at any place, even inside the housing, during operation. The housing does not prevent gas from entering.

Flameproof enclosure Ex d



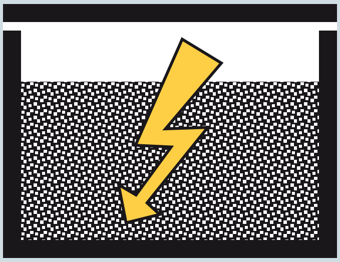
In the "flameproof enclosure" protection type, an explosion is prevented from spreading by the housing design. An explosion that occurs inside is not able to ignite the potentially explosive atmosphere surrounding the housing. This leads to very rugged housings.

The housings have covers and insertion 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 being carried over from inside the housing to the surrounding potentially explosive atmosphere.

In the case of cable and line entries in the Ex d protection type, it is not permitted to grease the thread or remove rust with a wire brush. Doing this could change the gap, thus destroying the protection principle. The manufacturer's specifications must be observed.

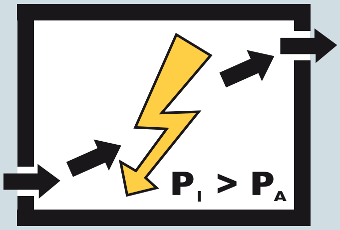
Molded, sand or oil encapsulation Ex m, Ex q, Ex o



The principle of the "molded encapsulation", "sand encapsulation", and "oil encapsulation" protection types 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 potentially explosive atmosphere from igniting.

Voltages from 10…11 kV can also be used in these protection types.

Pressurization Ex p



The "pressurization" protection type describes methods that use overpressure to prevent a potentially explosive atmosphere from entering into the housing or the control room.

The ambient pressure around the housing is always lower than inside.

Three forms of pressurization are possible (see table). In the case of static overpressure, the housing must be hermetically sealed. No loss of pressure occurs. 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.

The Ex p protection type 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 protection type, 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 via a different protection type.

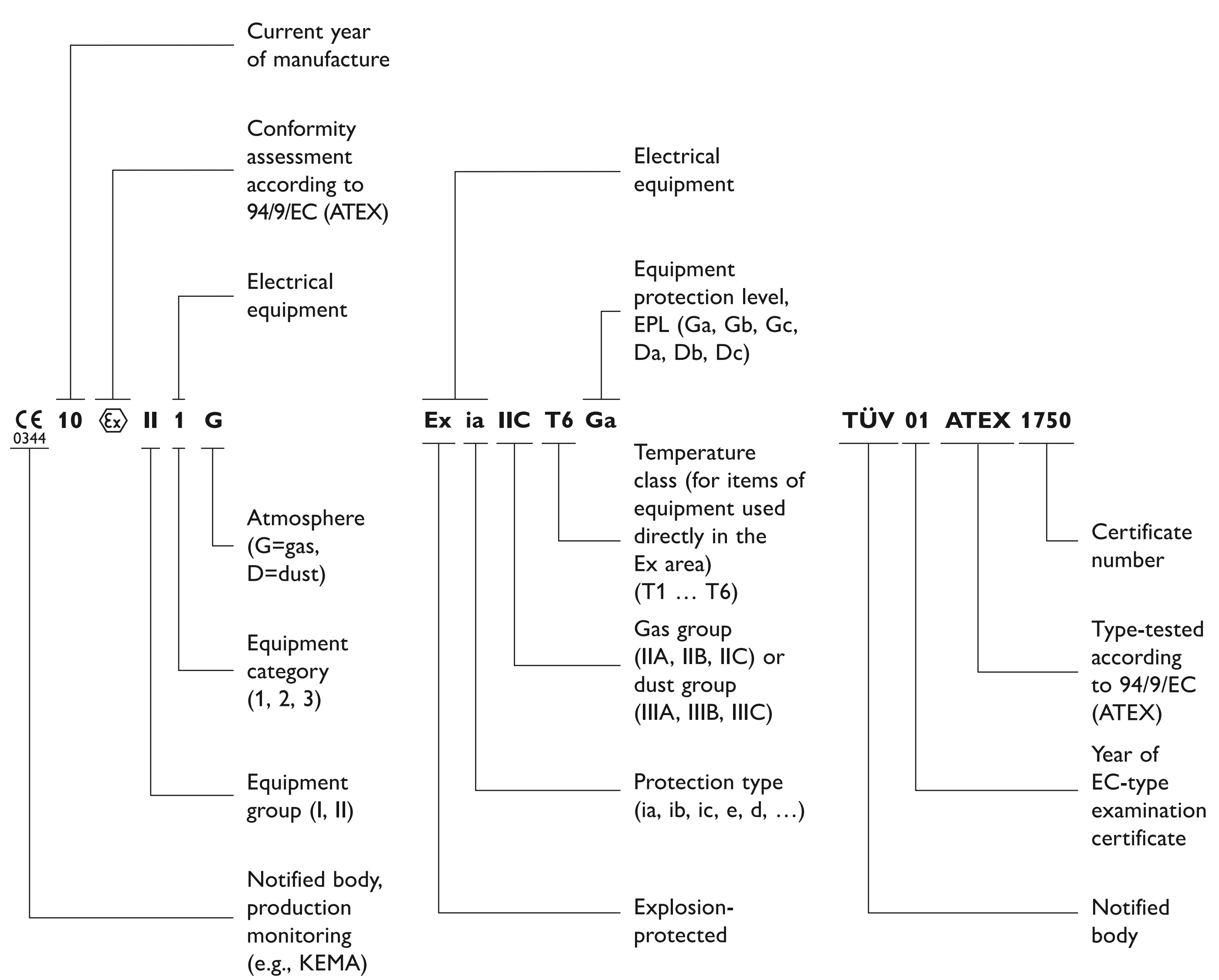
Possibilities of pressurization

Pressurization	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 potentially 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.	

1.4 Labeling of Ex products

Labeling for electrical equipment

Labeling according to ATEX Directive	Labeling according to EN 60079-0:2009	EC-type examination certificate



Relationship between categories, EPL, and zones

The equipment protection level (EPL) is a new addition to the EN 60079-0:2009 standard and specifies the equipment protection level of the device or component. The equipment protection level should be viewed in the same way as the categories used in the ATEX Directive. This now provides a way of assigning devices to zones that is simpler than labeling them according to their protection type.

	Equipment category according to ATEX Directive 94/9/EC	EPL (Equipment Protection Level)	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

Labeling according to ATEX Directive 94/9/EC

Examples of labeling according to ATEX Directive 94/9/EC and EN 60079-0

Gas - Ex	Number of the EC-type examination certificate/declaration of conformity U: component X: special installation conditions	Mark				
		... according to ATEX		… according to standard EN 60079-0:2006	… according to standard EN 60079-0:2009	… according to standard EN 60079-0:2009, alternative
Electrical equipment	IBExU 09 ATEX 1030	CE	Ex II 3 G	Ex nA II T4	Ex nA IIC T4 Gc	Ex nAc IIC T4
Item of associated electrical equipment	BVS 08 ATEX E 094 X	CE 0344	Ex II (1) G	[Ex ia] IIC	[Ex ia Ga] IIC	[Ex ia] IIC
Component	KEMA 07 ATEX 0193 U	0344	Ex II 2 G	Ex e II	Ex e IIC Gb	Ex eb IIC

Examples of labeling according to EN 61241-0 or EN 60079-0

Dust - Ex	Number of the EC-type examination certificate/declaration of conformity U: component X: special installation conditions	Mark		
		… according to standard EN 61241:2006	… according to standard EN 60079-0:2009	… according to standard EN 60079-0:2009, alternative
Electrical equipment	PTB 00 ATEX 0000 X	Ex tD A21 IP65 T80°C	Ex tb IIIC T80°C Db	Ex tb IIIC T80°C
Item of associated electrical equipment	TÜV 00 ATEX 0000	[Ex iaD]	[Ex ia Da] IIIC	[Ex ia] IIIC

In Europe, the labeling of items of equipment, components, and protection systems is based on the labeling laid down in directives and standards.

Labeling according to IECEx

Examples of labeling with IECEx certificate number and according to IEC 60079-0				
Gas - Ex	Number of the IECEx Certificate of Conformity U: component X: special installation conditions	Mark		
		…according to standard IEC 60079-0:2004	…according to standard IEC 60079-0:2007	…according to standard IEC 60079-0:2007, alternative
Electrical equipment	IECEx IBE 09.0002X	Ex nA II T4	Ex nA IIC T4 Gc	Ex nAc IIC T4
Item of associated electrical equipment	IECEx BVS 08.035X	[Ex ia] IIC	[Ex ia Ga] IIC	[Ex ia] IIC
Component	IECEx KEM 07.0057U	Ex e II	Ex e IIC Gb	Ex eb IIC

Examples of labeling according to IEC 61241-0 or 60079-0				
Dust - Ex	Number of the IECEx Certificate of Conformity U: component X: special installation conditions	Mark		
		…according to standard IEC 61241-0:2005	…according to standard IEC 60079-0:2007	…according to standard IEC 60079-0:2007, alternative
Electrical equipment	IECEx IBE 00.0000X	Ex tD A21 IP65 T80°C	Ex t IIIC T80°C Db	Ex tb IIIC T80°C
Item of associated electrical equipment	IECEx BVS 00.0000X	[Ex iaD]	[Ex ia Da] IIIC	[Ex ia] IIIC

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

Labeling in the USA

Labeling example for an item of associated electrical equipment

Classification of the item of equipment → 1M68

Certifying body in the USA: in this case, UL; c for Canada; us for USA → c UL us

Listed CD-No: 12345678 ← Control drawing no. (control document)

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

providing intrinsically safe circuits for use in

Class I, Div. 1, Groups A, B, C and D; ← Gases

Class II, Div. 1, Groups E, F and G; and ← Dusts

Class III, Hazardous Locations ← Fibers

suitable for circuits in Div 1*

** Acc. to NEC 500*

2 Installation of systems in potentially explosive areas

If systems are installed in potentially explosive areas, a great number of precautionary measures must be taken.

The employer/operator

- Classifies areas in which potentially explosive atmospheres may occur into zones;
- Guarantees that the minimum requirements are applied;
- Identifies access points to potentially explosive areas.

When selecting items of equipment, cables/lines, and construction, particular requirements must be observed.

Extract from Directive 1999/92/EC:

…

(1) Article 137 of the Treaty provides that the Council may adopt, by means of Directives, minimum requirements for encouraging improvements, especially in the working environment, to guarantee a better level of protection of the health and safety of workers.

…

(7) Directive 94/9/EC of the European Parliament and of the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres (5) states that it is intended to prepare an additional Directive based on Article 137 of the Treaty covering, in particular, explosion hazards which derive from a given use and/or types and methods of installation of equipment.

…

Risk analysis

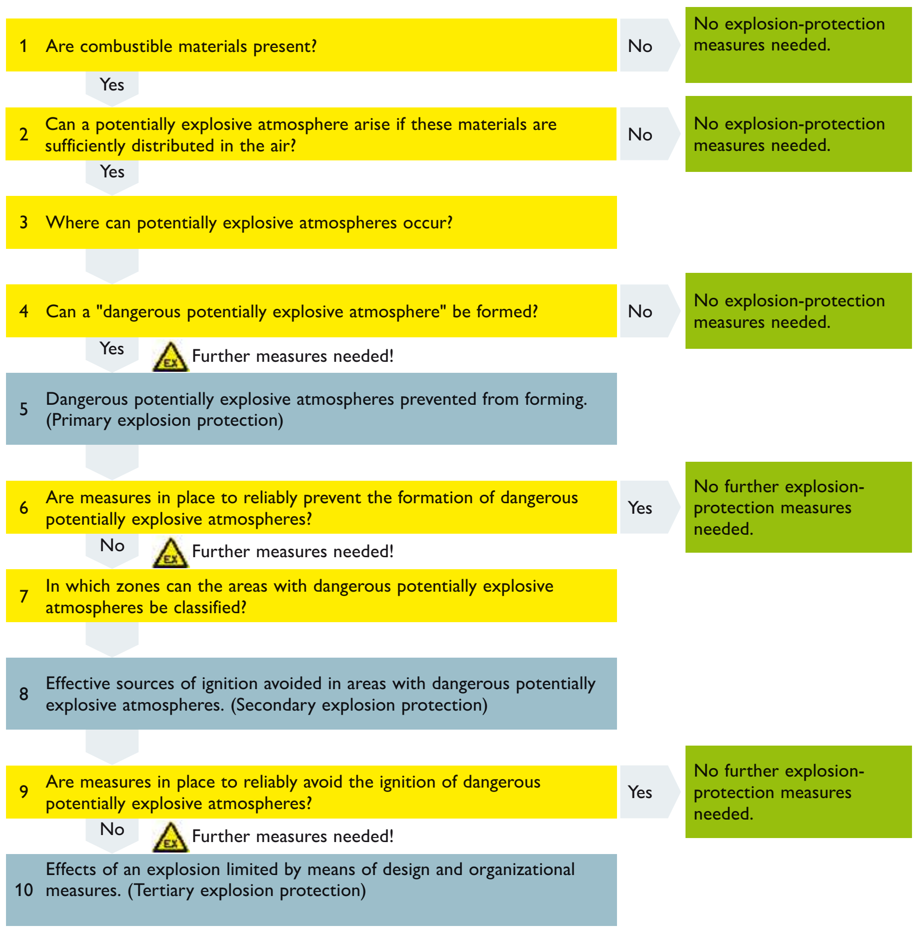
The operator of a system must carry out a detailed assessment based on, for example, standards EN 60079-10, EN 60079-14, and EN 1127-1 (see also the overview of standards on Page 12). This zones are determined and the permitted items of equipment selected based on this risk assessment. Every system must be examined in terms of 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 interrelations 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. If there is any doubt, it is advisable to refer to other experts. Risk assessment is the basis for all other measures, including the operation of the system.

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:



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 geographic 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 of relevance to an explosion
Risk assessment	See guide above
Protection concepts	Zone classification, protection types applied
Organizational measures	Training, written instructions, clearance for work

2.1 Installation of intrinsically safe circuits

Dimensioning of intrinsically safe circuits

Installation in the "intrinsic safety" protection type

The entire intrinsically safe circuit must be protected against the ingress of energy from other sources, and against electrical and magnetic fields. The installation technician or operator is responsible for providing proof of intrinsic safety, not the manufacturer.

Simple intrinsically safe circuits

Simple intrinsically safe circuits contain just one power source. To aid planning and installation, it is advisable to keep the operating instructions and the EC-type examination certificate(s) of the items of equipment used to hand. These must be referred to for the necessary parameters. In the first step, the criteria are checked according to the following table.

Checking use in a potentially explosive area

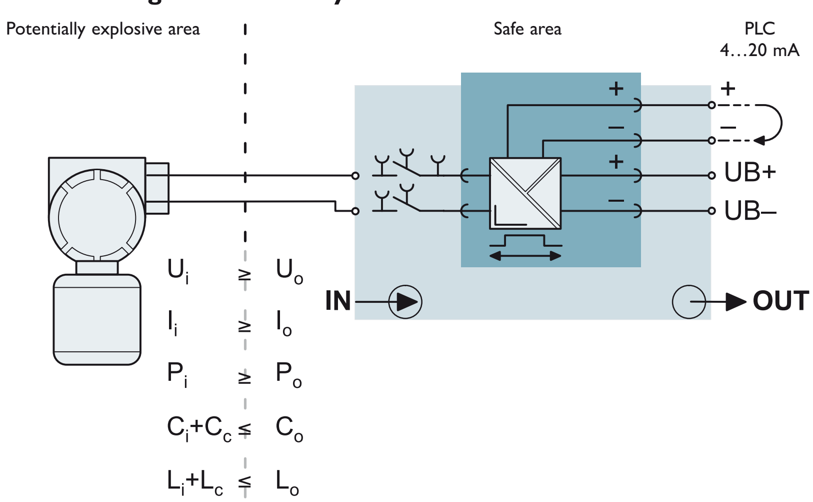
Criteria	Electrical equipment	Items of associated electrical equipment
Equipment group, field of application	II, G, D	II, G, D
Category	1, 2, 3	(1), (2), (3)
Group	IIA, IIB, IIC	IIA, IIB, IIC
Zone	0, 1, 2	0, 1, 2
Protection type	Ex ia, Ex ib	[Ex ia], [Ex ib]
Temperature class	T1…T6	--

The next step is to check the electrical data of the intrinsically safe circuit (voltage, current, power, capacitance, and inductance) in accordance with the figure below.

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 considerably restrict the length of cables or lines. As a recommended value, capacitance C_C can be taken to be approximately 140…200 nF/km and inductance L_C approximately 0.8…1 mH/km. Where there is any doubt, always assume the worst case.

Dimensioning of intrinsically safe circuits with an item of associated equipment



Common designations	Europe	USA
For field device:		
Max. input voltage	U_i	V_{max}
Max. input power	I_i	I_{max}
Max. internal capacitance	C_i	C_i
Max. internal inductance	L_i	L_i
For associated equipment:		
Max. output voltage	U_o	V_{oc}
Max. output power	I_o	I_{sc}
Max. external capacitance	C_o	C_a
Max. external inductance	L_o	L_a
For cable/line:		
Cable/line capacitance	C_c	C_{cable}
Cable/line inductance	L_c	L_{cable}

Intrinsically safe circuits with more than one power source

The dimensioning of an intrinsically safe circuit described here is only permissible, however, if a maximum of one concentrated power storage device C_i or L_i is present in the circuit.

If several concentrated power storage devices C_i and L_i are present, the maximum permissible capacitance C_o and inductance L_o must be halved before being compared with $C_i + C_c$ and $L_i + L_c$. C_i or L_i must be viewed as a concentrated power storage device if their respective value exceeds 1% of the maximum permissible external capacitance C_o or inductance L_o. The cable/line capacitance C_c or the cable/line inductance L_c do not apply as a concentrated capacitance or inductance.

The interconnection of several items of associated electrical equipment is not permitted for use in Zone 0.

If an intrinsically safe circuit for applications in Zone 1 and Zone 2 contains more than one item of associated equipment, proof must be provided from theoretical calculations or tests with the spark tester (in accordance with EN 60079-11). Whether or not a current addition is present must be taken into account. 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 characteristics are listed in Annex A and Annex B of EN 60079-14. When associated equipment with non-linear characteristics are interconnected, the evaluation on the basis of the non-load voltage and the short-circuit current does not lead to a result. The calculations can be performed on the basis of the PTB report PTB-ThEx-10, "Interconnection of non-linear and linear intrinsically safe circuits", however. This has been incorporated into EN 60079-25 (intrinsically safe systems). Here, graphical methods are used to evaluate intrinsic safety up to Zone 1.

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 to ground. The danger of electrostatic charging must be considered. Connecting via a resistance R = 0.2…1 MΩ in order to discharge the electrostatic charge does not apply 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 subcircuits, 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 realized immediately outside of Zone 0.

Systems with Zener barriers must be grounded to them. 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/or transient currents in the equipotential bonding lines must be taken into account.

Servicing and maintenance

No special authorization (e.g., fire certificate) is required for servicing intrinsically safe circuits. The cables of the intrinsically safe circuits can be short circuited or interrupted without endangering the protection type. Intrinsically safe items of equipment can be replaced (or plug-in modules removed) without the system having to be switched off. No exposed dangerous currents or voltages usually occur in intrinsically safe circuits, so they are safe for people. The measurement of intrinsically safe circuits requires approved, intrinsically safe measuring instruments. If the data of these measuring instruments is not taken into account, additional energy can enter into the intrinsically safe circuit. The permissible maximum values may then be exceeded and the requirements for intrinsic safety will no longer be fulfilled. The same holds true for all testers that are to be used.

Permitted conductor cross-sections for connection to ground

Number of conductors	Conductor cross-section*	Condition
At least 2 separate conductors	Min. 1.5 mm^2	Each individual conductor can carry the greatest possible current
One conductor	Min. 4 mm^2	

* *Copper conductors*

When cables/lines are installed, they must be protected against mechanical damage, corrosion, chemical, and thermal effects. This is a binding requirement in the "intrinsic safety" protection type.

The accumulation of a potentially 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.

Within the potentially explosive area, cables/lines should be laid without interruption as far as possible. If this cannot be done, the cables/lines may only be connected in a housing that is designed with a degree of protection that is approved for the zone. If this is not possible either for particular installation reasons, the conditions contained in standard EN 60 079-14 must be fulfilled.

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

- Protection against the ingress of external power.
- Protection against external electrical or magnetic fields. Possible cause: High-voltage overhead cable or single-phase high-voltage cables.
- Single-core non-sheathed cables of intrinsically safe and non-intrinsically safe circuits may not be routed in the same cable.

Cables/lines for Zone 1 and 2

Cable/Line	Requirement	
Stationary item of equipment	Sheath	Thermoplastic, thermosetting plastic, elastomer or metal-insulated with a metal sheath
Portable, trans-portable item of equipment	Outer sheath	Heavy polychloroprene, synthetic elastomer, heavy rubber tubing or comparably rugged structure
	Minimum cross-sec-tional area	1.0 mm^2
Stranded cables and lines	Version	• Light rubber tubing without/with polychloroprene sheathing • Heavy rubber tubing without/with polychloroprene sheathing • Plastic-insulated cable, comparably heavy rubber tubing

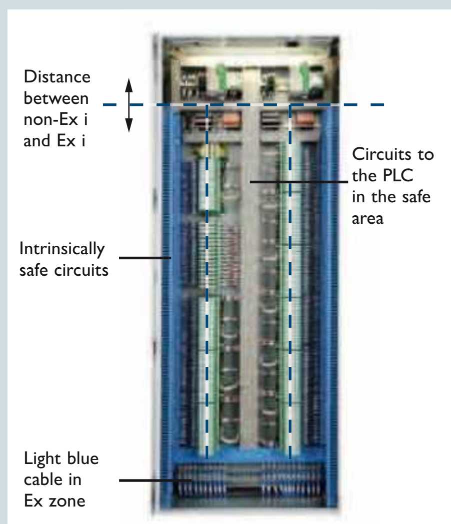
- Several intrinsically safe circuits can be routed in multi-strand cables or lines.
- In the case of armored, metal-sheathed or shielded cables/lines, intrinsically safe and non-intrinsically safe circuits can be laid in one and the same cable duct.

In the control cabinet, the intrinsically safe circuits should be clearly marked. The standard does not stipulate a uniform process, but only indicates that the identification should preferably be done by means of a light blue color. The neutral conductors of power cables are usually also identified by the color blue. In this case, intrinsically safe circuits should be identified in a different way, to prevent mix ups. A clear arrangement and spatial separation is advantageous in the control cabinet.

Conductive shields may only be grounded at one point, which is usually found in the non-explosive area. See also the section titled "Grounding in intrinsically safe circuits" (Page 31) and the table on Page 33.

Selection criteria for cables/lines for the "intrinsic safety" protection type

Criterion	Condition	Note
Insulated cables/lines	Test voltage ≥ 500 V AC ≥ 750 V DC	Conductor-ground, conduc-tor-shield, and shield-ground
Diameter of individual conductors	≥ 0.1 mm	For fine-strand conductors too
Fine-strand cables	Protect against splicing	For example, with ferrules
Multi-strand cables/ lines	Permitted	Take into account the fault monitoring conditions in EN 60079-14
Parameters	(C_C and L_C) or (C_C and L_C/R_C)	If in doubt: worst case



Special cases for grounding conductive shields in intrinsically safe circuits		
	Reason	Conditions
a	Shield has a high resistance, additional braided shield against inductive interference	Rugged ground conductor (min. 4 mm^2), insulated ground conductor and shield: insulation test 500 V, 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 ensured to a great extent
c	Multiple grounding via small capacitors	Total capacitance not over 10 nF

Distances to connection terminal blocks

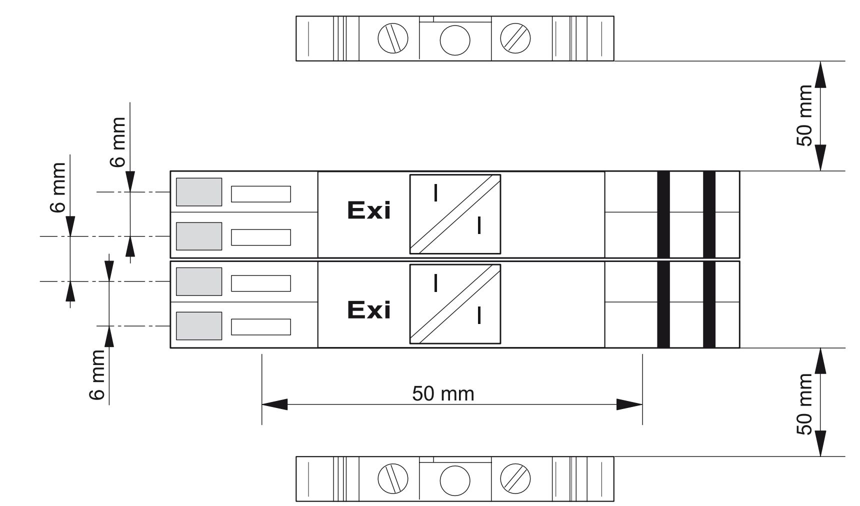
Between different intrinsically safe circuits

The air distances between terminal blocks in different intrinsically safe circuits must be at least 6 mm. The air distances 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 identified.

Between intrinsically safe and other circuits

The distance at modular 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/conductors of intrinsically safe circuits may not come into contact with a non-intrinsically safe circuit, even if they should become loose from the modular terminal block of their own accord. The cables/conductors must be shortened during installation accordingly.



Spacing acc. to EN 60079, Section 6.2.1 or Fig. 1

Special requirements in Zone 0, Europe

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

2.2 Surge protection in Ex areas

Surge protection for intrinsically safe circuits

Surge voltages, which are usually caused by switching operations, fuse tripping, frequency transducers or lightning strikes, are an important issue when it comes to retaining the functionality and availability of electrical systems.

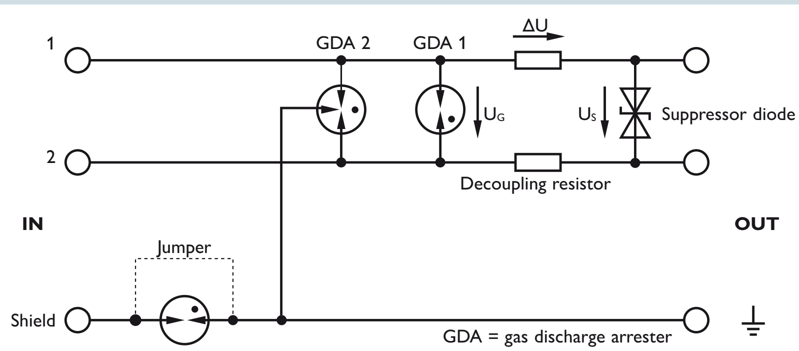
These disturbance variables are rapidly changing noise emissions (transients), which can reach amplitudes of several kilovolts in a few microseconds.

If a surge voltage occurs, this results in dangerous potential differences, which may lead to maloperations, short-term interruptions in function or, in the worst-case scenario, destruction. Such potential differences can only be limited to non-hazardous values via the consistent use of surge protection devices (SPDs) on the equipment to be protected. SPDs in Ex zones must fulfill the requirements of DIN EN 60079-14 in order to avoid dangerous potential differences arising from surge voltages. This standard stipulates that the device must be able to reliably master at least 10 pulses of pulse form 8/20 µs with a minimum discharge surge current of 10 kA, if dangerous potential differences can be coupled into Ex Zone 0.

PLUGTRAB PT 2xEX(I) surge protection device

This requirement is met via the use of gas discharge arresters (GDAs); see the figure titled "Protective circuit of the SPD SP-PT-EX(I)-24DC". The required insulation strength of 500 V to ground according to DIN EN 60079-11 is achieved thanks to the specially dimensioned GDA 2.

Items of equipment usually have an insulation strength of 1.5 kV to ground and the dielectric strength between the wires often only amounts to a couple of hundred volts or less. Although a GDA is sufficient for maintaining the insulation strength in the event of transients, additional suppressor diodes must be used to provide the dielectric strength between the wires. These semiconductor components are characterized by a very fast response to transients and a low voltage limitation



Protective circuit of the SPD S-PT-EX(I)-24DC

SURGETRAB surge protection device (through or parallel wiring)
S-PT-EX(I)-24DC
S-PT-EX-24DC
(labeling according to ATEX)

– however, their discharge capacity is just a couple of hundred amperes. Therefore, the use of multi-stage SPDs, such as SURGETRAB, is recommended. If a transient occurs, the suppressor diode limits the voltage until the sum of the residual voltage of the suppressor diode U_S and the voltage drop at the decoupling resistors ΔU corresponds to the operate voltage of the GDA 1 U_G (Kirchhoff's law). So while the suppressor diode between the wires provides for a fast response with a low protection level, the GDA achieves a high discharge capacity of 10 kA.

In practice, it is beneficial if a decision as to whether the shield should make contact with ground directly or indirectly via a GDA can be made at the installation location itself. If the SURGETRAB is used, for example, this can be achieved by detaching a preinstalled jumper from GDA 3 (see circuit diagram).

Example - Deep tank farm

A level measurement device on a tank is often connected to the control board via long cable paths of, for example, 100 m.

Due to the potentially explosive atmosphere which is always present inside the tank, Ex Zone 0 prevails there. The measured values are transmitted to the control board in the form of current signals (4 - 20 mA), since they are insensitive to external interference. In order to prevent the grounding system's inadmissibly high potential differences from occurring, equipotential bonding is first set up between the control board and the deep tanks.

The example shown here assumes a lightning strike of 30 kA with a 10/350 µs pulse*. Half of the current is discharged via ground, while the other half enters the system directly. Therefore, it is assumed that 15 kA flow to the control board via the equipotential bonding line. If the equipotential bonding line has a copper cross-section of 95 mm², this results in the following calculation for the ohmic voltage drop between the control board and the deep tank:

$$\hat{U}_R = \frac{\hat{i}_B}{2} \cdot R_{CU}, \text{ where } R_{CU} = \frac{l}{\partial \cdot A} \text{ and}$$

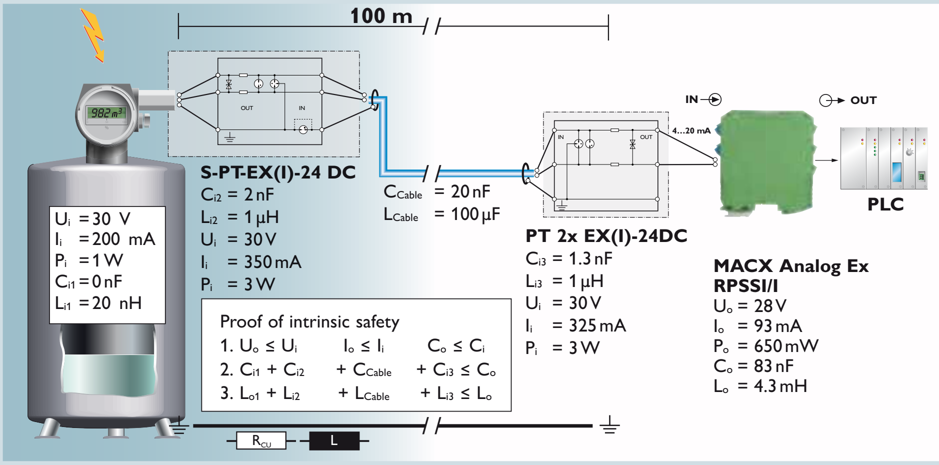
$$\partial = 17.3 \frac{m\Omega \cdot mm^2}{m}$$

$$\hat{U}_R = \frac{30\ kA}{2} \cdot 17.3 \frac{m\Omega \cdot mm^2}{m} \cdot \frac{100\ m}{95\ mm^2}$$

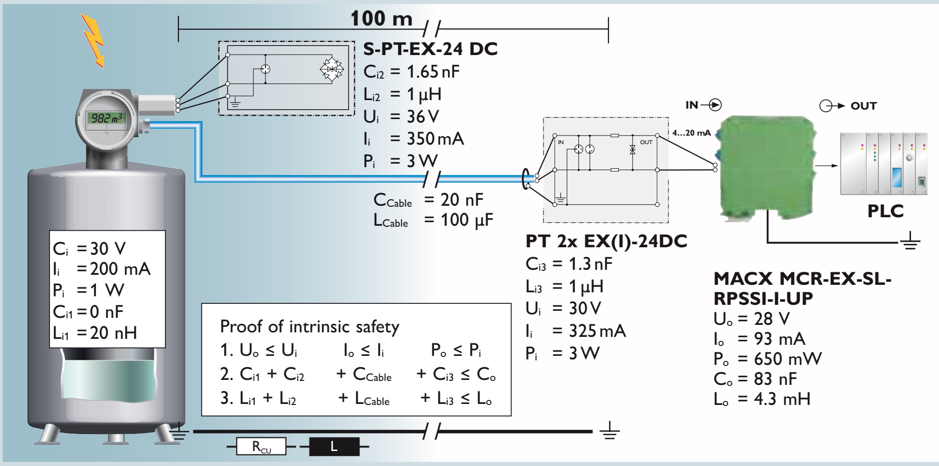
$$\underline{\hat{U}_R = 273\ V}$$

At first glance, the combination of equipotential bonding lines and the insulation strength of 500 V required by the relevant standard seems to offer sufficient protection from partial lightning currents in intrinsically safe systems.

However, in addition to the resistance per unit length, the cable also has an inductance per unit length L'. For a round copper conductor, a cross-section-independent inductance per unit length L' ≈ 1 µH/m is assumed in practice. If the previously defined lightning current of 15 kA in pulse form 10/350 µs flows along the equipotential



Level measurement: Protection provided by SURGETRAB S-PT-EX(I)-24DC in through wiring and PLUGTRAB PT-2xEX(I)-24DC



Level measurement: Protection provided by SURGETRAB S-PT-EX-24DC in parallel wiring and PLUGTRAB PT 2xEX(I)-24DC

bonding line toward the control board, Faraday's law states that an inductive voltage drop of 150 kV is generated:

$$U_L\ (t) = -\ L \cdot \frac{di_{B(part)}}{dt}$$

$$\hat{U}_L\ (t) \approx -\ L' \cdot l \cdot \frac{\Delta i_{B(part)}}{\Delta t}$$

$$\hat{U}_L \approx -1 \frac{\mu H}{m} \cdot 100\ m \cdot \frac{15\ kA}{10\ \mu s}$$

$$\underline{\hat{U}_L \approx -150\ kV}$$

Intrinsically safe circuits that run between the deep tank and the control board are thereby destroyed. This effect can only be avoided through the consistent use of surge protection devices.

These SPDs should be installed as close as is practically possible to the entrance to Zone 0. A distance of 1 m should not be exceeded.

The cables between the measuring sensor and the SPD must be designed such that they are protected against direct lightning interference. One possibility here would be to install the cables in a metal conduit.

SPDs such as the SURGETRAB are recommended for protecting sensor heads from surges, as they have been specially developed for this application. They are integrated directly into the cable run and screwed into the sensor heads which are to be protected.

* *10/350 µs = pulse rise time 10 µs, decay time to half-value 350 µs*

2.3 Connection technology

Modular terminal blocks

Modular terminal blocks with increased safety Ex e

Modular terminal blocks must meet the requirements for the connection of external conductors.

The 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 and creepage distances; insulating materials which are resistant to temperature and aging
- Protection against the conductor spreading during connection
- Protected against accidental loosening
- Conductors must not be damaged during connection
- Continuous sufficient contact pressure
- Contact reliability if temperature fluctuates
- No transmission of contact pressure via the insulating material
- Multi-conductor connection only at suitable terminal points
- Elastic element for multi-strand conductors of 4 mm^2 and up
- Specified torque for screw connection terminal blocks

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

- Rated insulation voltage
- Rated voltage
- Connectable conductor cross-sections
- Operating temperature range
- Temperature class.

Modular terminal blocks are used as approved components in the potentially explosive area. They are used in the connection spaces of Ex equipment.

Therefore, they are permitted for use in Zone 1 and 2 for gases and in 21 and 22 for dusts. The requirements for IP protection are fulfilled by the connection space in accordance with the relevant protection type.

The approval of components serves as the basis for certifying a device or protection system. The modular terminal block is identified as a component by the certificate number (suffix "U" according to European standard) or the approval mark (e.g., UL: Recognition Mark •).

Modular terminal blocks with the "increased safety Ex e" protection type must be labeled.

The elements of the label are described using the example of the QTC 2,5 type.

Rating plate		
	Labeling requirements according to EN/IEC 60079-0 for ATEX and IECEx	
	Manufacturer's name or trademark	PHOENIX CONTACT or
	Type designation	QTC 2,5
	Protection type mark	Ex e II
	EC-type examination certificate number according to ATEX	KEMA 05 ATEX 2148 U
	Certificate number according to IECEx	IECEx KEM 07.0010 U

Packaging label		
	Labeling requirements according to ATEX Directive 94/9/EC, Annex II	
	Manufacturer's name and address	PHOENIX CONTACT 32825 Blomberg, Germany
	Type designation	QTC 2,5
	Date of manufacture	09/13/2010 (example)
	ID no. of the notified body (KEMA)	0344
	Type-tested according to ATEX Directive 94/9/EC	Ex
	Category	2
	Equipment group	II
	Identification letter for gas explosion protection	G
	Identification letter for dust explosion protection	D

Important notes:

Modular terminal blocks are designed for use in temperature class T6. Information about other temperature classes and the operating temperature range can be found on the EC-type examination certificate and in the installation instructions. If terminal blocks are used, the installation instructions regarding the use of accessories must also be observed.

Modular terminal block in Ex e

Modular terminal block in Ex e housing

Modular terminal blocks with intrinsic safety Ex i

With the "intrinsic safety" protection type, no special requirements are made for conductor connections concerning secured screws, solder connections, plug connections, etc. The current, voltage, and power values are so low in circuits proven to be intrinsically safe that there is no danger of explosion.

Modular terminal blocks and connectors are considered to be passive components where intrinsic safety is concerned, which means that no special type tests have to be carried out for them. However, strict demands are placed on the air distances between adjacent terminal blocks and between terminal blocks and grounded metal parts. The air distance between the external connections of two neighboring intrinsically safe circuits must be at least 6 mm. The minimum air distance between non-insulated connections and grounded metal parts or other conductive parts, on the other hand, need only be 3 mm.

Air and creepage distances, as well as distances through rigid insulation, are specified in EN 60079-11, Section 6.3 and Table 5, for example.

No special labeling is prescribed for passive components such as modular terminal blocks or connectors.

However, it is usual for the terminal housing to be blue in color so that intrinsically safe circuits are clearly identified.

Blue terminal housing for intrinsically safe circuits

Ex e and Ex i modular terminal blocks in the same housing

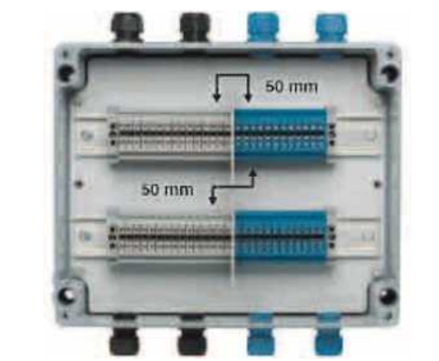
In electrical equipment, such as terminal boxes, both intrinsically safe (Ex i) and increased safety (Ex e) circuits can be combined.

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 modular terminal block. The distance between the modular terminal blocks must be at least 50 mm.

Standard wiring procedures should also be followed so that it will be unlikely for circuits to 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 made in all directions around the partition plates. 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.

Air distance provided by partition plate between intrinsically safe circuits and other circuits.



Air distances to intrinsically safe circuits and other circuits must also be observed even when there are several DIN rails.

Partition plate between DIN rails to safeguard air distance.

2.4 Housing entries

Cable/line entry and conduit systems

Two installation techniques are used worldwide.

In Europe, cable/line entries in the "flameproof enclosure" or "increased safety" protection type are most commonly used. In the USA and Canada, the conduit system is traditionally used.

Cable/line entry

Cable/line entries are most frequently designed in the "flameproof enclosure Ex d" or "increased safety Ex e" protection type.

Flameproof enclosure cable/line entries are dust ignition-proof and are used in conjunction with flameproof enclosure housings.

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

Conduit system

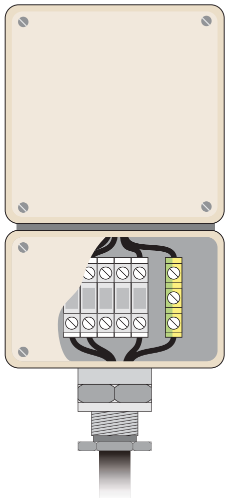
In the USA, particular importance is placed on providing the cables/lines with a high degree of mechanical protection, which is why the conduit system has become very widespread here.

Comparison of cable/line entry with conduit system

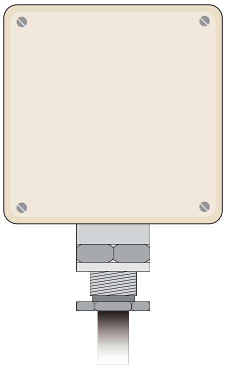
Compared to cables/lines or cable/line entries, conduit systems are more laborious to install.

When doing so, it must be ensured that the ignition lock is properly sealed; if it is not, protection is not guaranteed. One of the crucial factors in this regard is the position of the opening for the molding compound. Furthermore, condensation can easily form in conduit systems,which in turn can cause ground faults and short circuits as a result of corrosion.

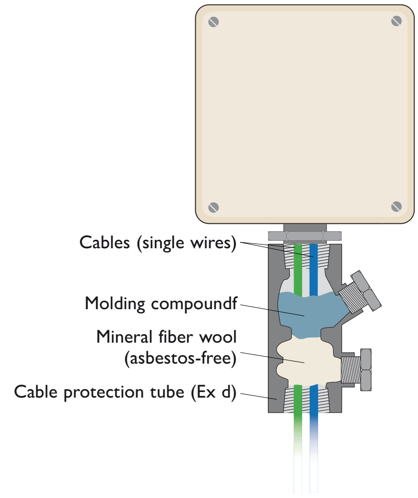
The cable/line entry, on the other hand, is designed so that the installation does not depend on the respective fitter.



Cable system with indirect entry



Cable system with direct entry



Conduit system with ignition lock (seal)

2.5 Installation examples

Installation of electrical devices for the purpose of transmitting signals

Electrical equipment operated in systems with potentially explosive areas is subject to different requirements, depending on how it is used. For example, electrical equipment could be used in the following fields of application if analog signals are being transmitted:

- Sensors/actuators can be located in Zone 0, Zone 1 or Zone 2
- Signal transmitters can be located in Zone 1, Zone 2 or the safe area
- The controller, e.g., PLC, is in the safe area.

Examples of the installation of electrical devices for the purpose of transmitting signals can be found in the figure on Page 41.

Intrinsically safe signal transmission in potentially explosive areas

Sensors/actuators to be installed in Zone 0 are primarily designed in the "intrinsic safety Ex ia" protection type. The intrinsically safe sensors/actuators are connected to associated equipment in the "intrinsic safety" [Ex ia] protection type, such as MACX MCR-Ex isolators. The EC-type examination certificate for the Ex i isolator provides the safety-related data required to dimension the intrinsically safe circuit. The MACX MCR-Ex isolators also provide electrical isolation between the circuit and a controller in the sensor/actuator circuit.

If Ex i isolators are only designed in the [Ex ia] protection type, they may only be installed outside 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 protection type, such as "flameproof enclosure". If an Ex i isolator is mounted in a flameproof enclosure housing, it can also be installed in Zone 1. But Ex i isolators can also be designed in a different protection type, e.g., "n", for the purpose of intrinsic safety [Ex ia]. If this is the case, they can be installed directly in Zone 2, taking certain conditions into account.

The installation conditions are specified in the operating instructions of the Ex i isolator and may include the condition, for example, that a suitable and approved housing (EN 60079-15 and EN 60079-0) with a minimum degree of protection of IP54 is used. However, special conditions for installation in a housing are usually only necessary if the housing of the Ex i isolator itself does not meet the requirements of EN 60079-15 and EN 60079-0.

The Ex i isolators can also be used for sensors/actuators designed in the Ex ib or Ex ic protection type and approved for Zone 1 or 2.

Non-intrinsically safe signal transmission in potentially explosive areas

Alongside intrinsically safe signal transmission in potentially explosive areas, there are also sensors/actuators which are designed in other protection types, such as "flameproof enclosure" or "n". Non-intrinsically safe isolators, e.g., MINI Analog, are permissible for use in such cases.

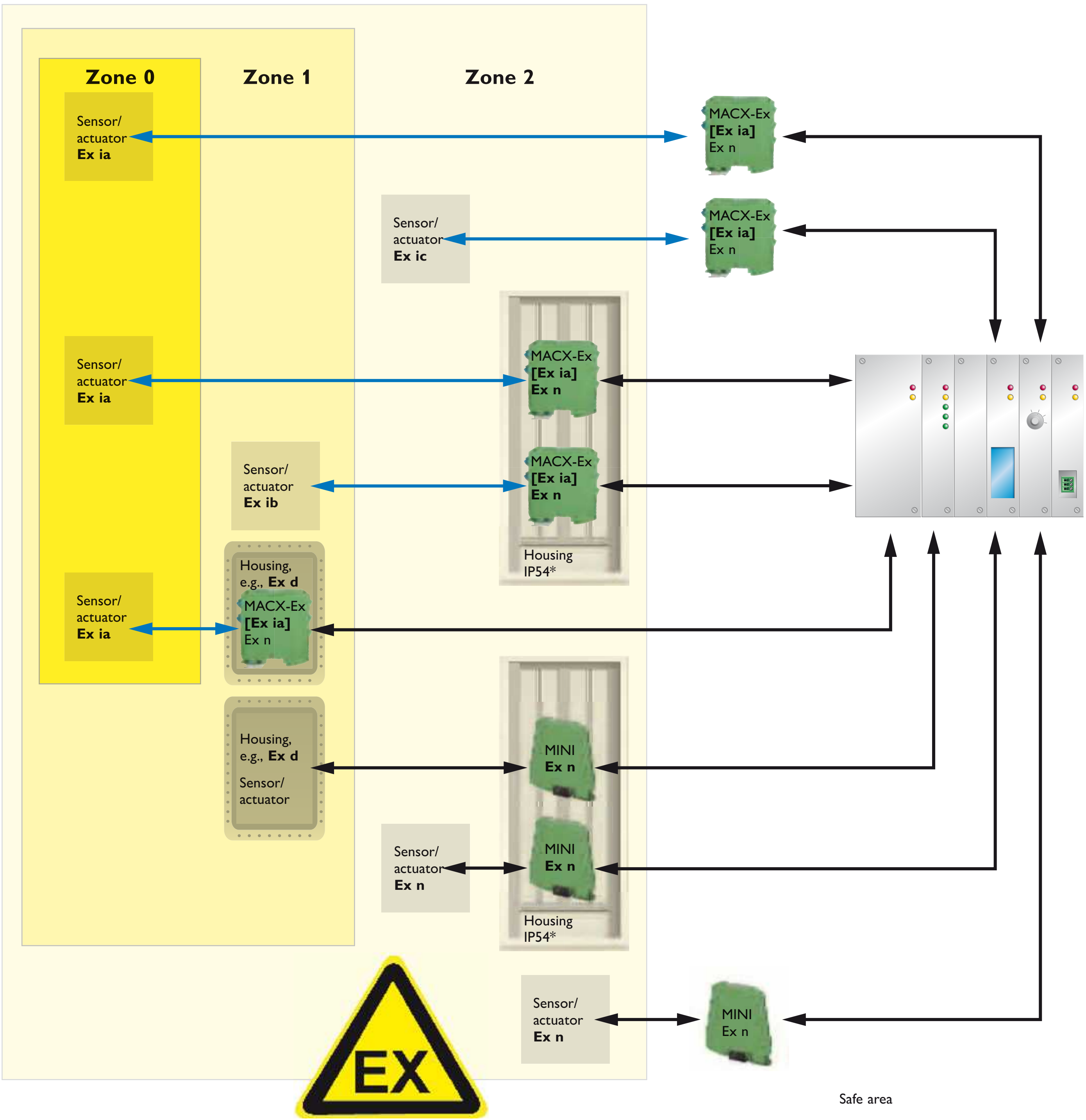
Even non-intrinsically safe isolators must be designed in a suitable protection type if they are to be used in Zone 2. The MINI Analog family is designed in the "n" protection type for this purpose and must be installed in Zone 2 in a suitable and approved housing (EN 60079-15 and EN 60079-0) with a minimum degree of protection of IP54.

A sensor/actuator of the "n" protection type can be connected in Zone 2 to a MINI isolator or an Ex i isolator, for example. 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 labeled 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 a flameproof enclosure housing or if they have their own flameproof enclosure housing, they can also be installed in Zone 1. The "n" protection type is also suitable if sensors/actuators are to be used in Zone 2.

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 installations in areas with a danger of gas explosions can be found in EN 60079-14. EN 61241-14 should be observed for information on the installation of electrical equipment in areas containing combustible dust. Other important factors when it comes to running systems in potentially explosive areas are inspection, maintenance, and repairs. Specifications in this regard can be found in EN 60079-17 and EN 60079-19.

Example of the installation of electrical devices for the purpose of transmitting signals



** Use of a suitable housing approved for use in Zone 2*

2.6 Proof of intrinsic safety

General considerations

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.

The comparisons specified here must be performed when selecting appropriate devices for the application in question.

Comparison of the labeling of an intrinsically safe field device in Zone 0 and an item of associated equipment

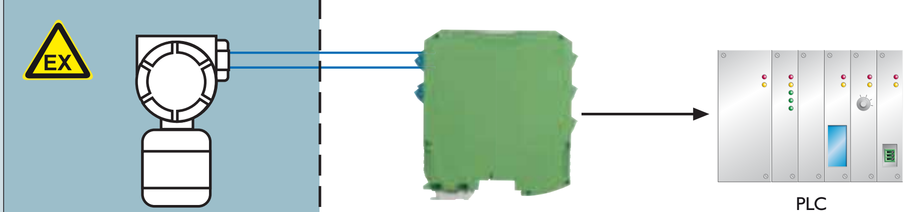
Field device	Evaluation of the Ex mark	Associated equipment
Ex II **1** G Ex ia IIB T6	Category of the field device corresponds to the specified zone	
Ex II **1** G Ex **ia** IIB T6	Protection type is permitted in the specified zone	
Ex II 1 **G** Ex ia **IIB T6**	The device is permitted for use in the prevailing gas atmosphere	
	Associated equipment is identified as such by means of brackets	Ex II **(1)** G **[** Ex ia **]** IIC
Ex II **1 G** Ex ia IIB T6	Category of the associated equipment at least corresponds to the category of the field device	Ex II **(1) G** [Ex ia] IIC
Ex II 1 G Ex **ia** IIB T6	Protection type of the associated equipment matches that of the field device	Ex II (1) G [Ex **ia**] IIC
Ex II 1 G Ex ia **IIB** T6	The associated equipment is approved for the same gas group or one of a higher order	Ex II (1) G [Ex ia] **IIC**

Description of safety-related data

Description	Abbreviation
For field device:	
Max. input voltage	U_i
Max. input power	I_i
Max. internal capacitance	C_i
Max. internal inductance	L_i
For associated equipment:	
Max. output voltage	U_o
Max. output power	I_o
Max. external capacitance	C_o
Max. external inductance	L_o
For cable/line:	
Cable/line capacitance	C_c
Cable/line inductance	L_c

Dimensioning of intrinsically safe circuits

Example of a circuit | Safe area



PLC

Field device
Ex II 1 G Ex ia IIB T6

Item of associated electrical equipment, e.g., MACX MCR-EX-SL-RPSS EI
Ex II (1) G [Ex ia] IIC

$U_i \geq U_o$

$I_i \geq I_o$

$P_i \geq P_o$

$C_i + C_c \leq C_o$

$L_i + L_c \leq L_o$

Analog IN

Function:

The devices transmit analog signals from sensors in the field to a controller using an electrically isolated method.

Input isolator:

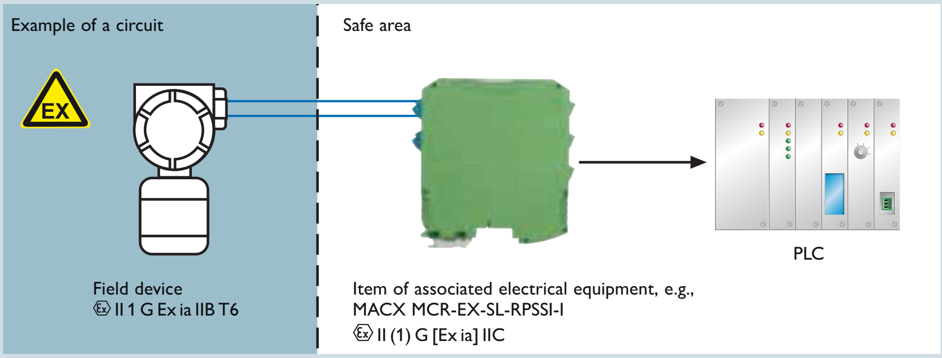
The sensor in the field is not supplied with power by the input isolator.

Repeater power supply:

Additionally supplies the sensor with the required power.

HART repeater power supply:

Additionally modulated digital data signal is transmitted.



Comparison of the safety-related data from the hazardous area approval for a repeater power supply

Field device*	Cable/Line		Associated equipment	Example MACX MCR-EX-SL-RPSSI-I
U_i		≥	U_o	25.2 V
I_i		≥	I_o	93 mA
P_i		≥	P_o	587 mW
C_i	+ C_C (140…200 nF/km approx.)	≤	C_o	IIC: 107 nF
L_i	+ L_C (0.8…1 mH/km approx.)	≤	L_o	IIC: 2 mH

* *The values for the field device can be derived from the relevant EC-type examination certificate. This comparison is based on the assumption that C_i is < 1% of C_o and L_i is < 1% of L_o.*

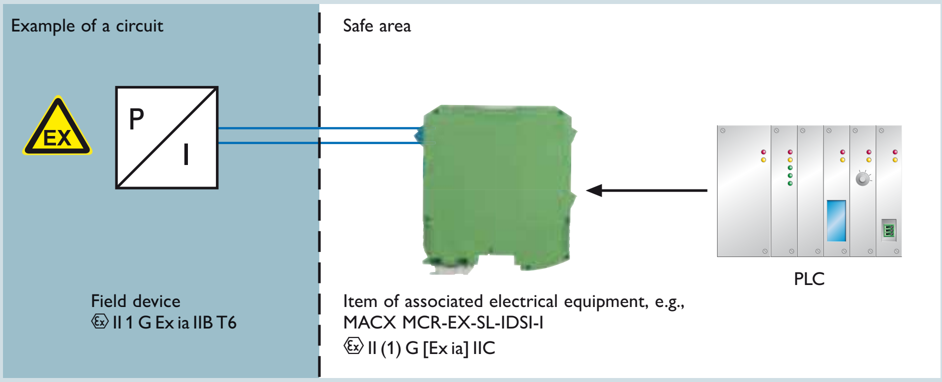
Analog OUT

Function:

The devices transmit analog signals from a controller to an actuator in the field using an electrically isolated method.

Output isolator:

The output isolator can also be Smart-capable. In this way, actuators in the field can be configured using the HART protocol.



Comparison of the safety-related data from the hazardous area approval

Field device*	Cable/Line		Associated equipment	Example MACX MCR-EX-SL-IDSI-I
U_i		≥	U_o	27.7 V
I_i		≥	I_o	92 mA
P_i		≥	P_o	636 mW
C_i	+ C_C (140…200 nF/km approx.)	≤	C_o	IIC = 85 nF
L_i	+ L_C (0.8…1 mH/km approx.)	≤	L_o	IIC = 2 mH

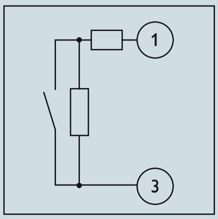
* *The values for the field device can be derived from the relevant EC-type examination certificate. This comparison is based on the assumption that C_i is < 1% of C_o and L_i is < 1% of L_o.*

Digital IN

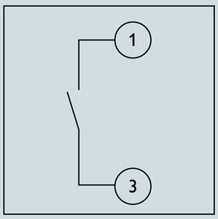
NAMUR isolation amplifier

The devices 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 isolation amplifier, the signal is transferred to the controller as a binary signal either through a relay or through a transistor.

An additional resistance circuit enables open circuit detection to be performed even for simple switches.

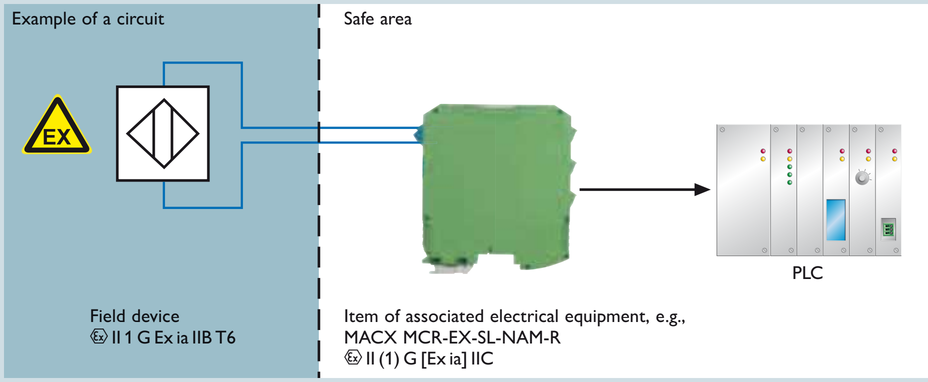


With open circuit detection



Without open circuit detection

The resistance is used to ensure that a minimum current is always flowing, even when the switch is open. In this way, a cable break can be identified.



Comparison of the safety-related data from the hazardous area approval				
Field device*	Cable/Line		Associated equipment	Example MACX MCR-EX-SL-NAM-R
U_i		≥	U_o	9.6 V
I_i		≥	I_o	10 mA
P_i		≥	P_o	25 mW
C_i	+ C_C (140…200 nF/km approx.)	≤	C_o	IIC = 510 nF
L_i	+ L_C (0.8…1 mH/km approx.)	≤	L_o	IIC = 100 mH

* *The values for the field device can be derived from the relevant EC-type examination certificate or will have to be determined specifically for simple electrical equipment.*
This comparison is based on the assumption that C_i is < 1% of C_o and L_i is < 1% of L_o.

In the case of simple electrical equipment, e.g., simple switches, only the inductance and capacitance values of the cables/lines are used for the comparison of safety-related data.

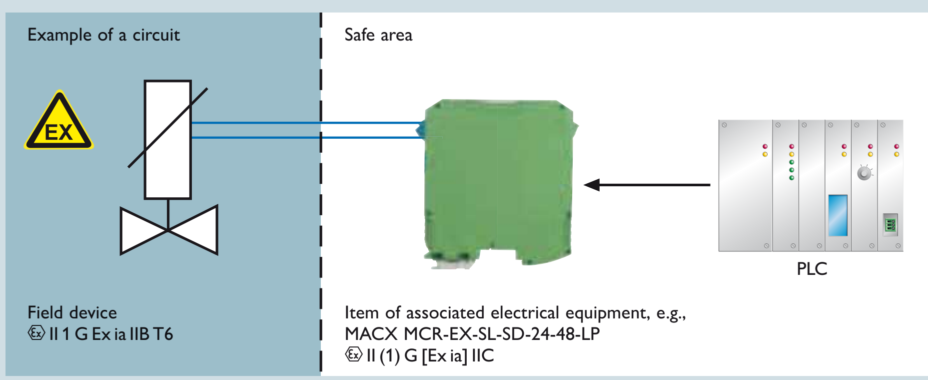
For additional requirements relating to "simple electrical equipment", see Page 21.

Digital OUT

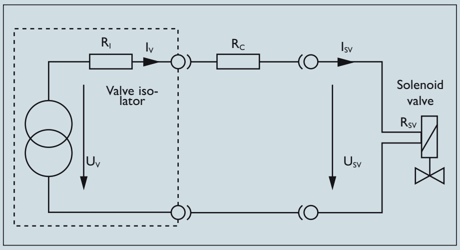
Solenoid driver

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.



Dimensioning



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 I_{SV} (the copper resistance of the winding depends on the ambient temperature)

Dimensioning takes place in several steps.

1. Checking safety-related data
   $U_i \geq U_O$
   $I_i \geq I_O$
   $P_i \geq P_O$
2. Checking function data
   $I_V \geq I_{SV}$
3. Determining the max. permissible cable resistance
   $$R_C = \frac{U_V}{I_{SV}} - R_i - R_{SV}$$
   $R_C > 0\ \Omega$, otherwise the function is not guaranteed.

Recommended value for cables/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	180 nF/km approx.
Cable inductance	0.8 mH/km approx.

Example for the solenoid driver MACX MCR-EX-SL-SD-24-48-LP

1. Checking safety-related data

Comparison of the safety-related data from the hazardous area approval

Field device*	Example valve	Cable/ Line	Example 100 m		Associated equipment	Example MACX MCR-EX-SL-SD-24-48-LP
U_i	28 V			≥	U_o	27.7 V
I_i	115 mA			≥	I_o	101 mA
P_i	1.6 W			≥	P_o	697 mW
C_i	Negligible	$+C_C$	+ 18 nF	≤	C_o	80 nF
L_i	Negligible	$+L_C$	+ 0.08 mH	≤	L_o	5.2 mH

** The values for the field device can be derived from the relevant EC-type examination certificate.*

2. Checking function data

Valve isolator
U_V = 21 V, R_i = 133 Ω, I_V = 45 mA
Valve
$R_{SV\ 65°C}$ = 566 Ω, I_{SV} = 23 mA
$I_V \geq I_{SV}$

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

3. Determining R_C

$$R_C = \frac{U_V}{I_{SV}} - R_i - R_{SV} = \frac{21.9\ V}{0.023\ A} - 566\ \Omega - 133\ \Omega = 253.2\ \Omega$$

The calculation yields the result that a resistance of 253.5 Ω is available for the cable.

Recommendation: The actual cable resistance should have a reserve of 25 Ω for the valve to function correctly.

With a cable cross-section of 0.5 mm², the maximum possible cable length is 3.17 km, with a reserve of 25 Ω. However, because the safety-related data from the hazardous area approval also has to be taken into account, the maximum permissible cable length for the example is 444 m.

Temperature transducer

Temperature transducers convert measurement signals from variable resistors (e.g., Pt100) or thermocouples (e.g., J, K) into standard signals 0…20 mA, 4…20 mA.

2-, 3-, or 4-wire measurement technology can be used for Pt100 resistors.

Temperature measurement

The temperature inside a heating oil tank is to be monitored. The measurement is performed using a Pt100 resistor. This can be viewed as an item of simple electrical equipment according to EN 60079-11, since it is passive. 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.

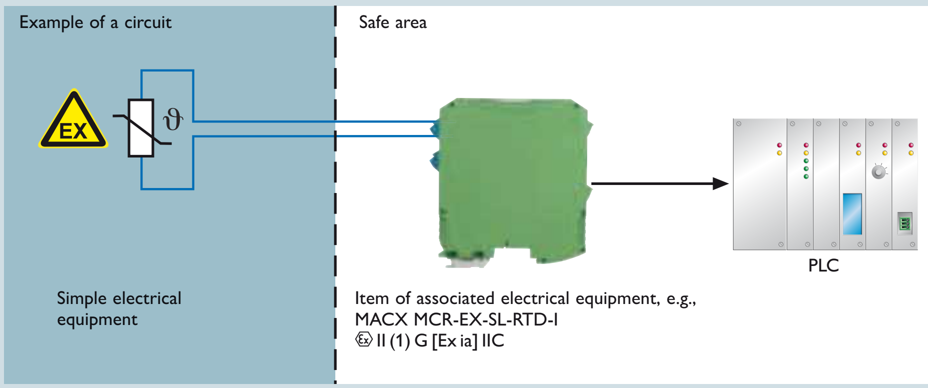
If certified, intrinsically safe sensors are used, this reduces the amount of testing work required.

There are two possibilities for converting the measurement signal into a standard signal for the controller.

Case I

The measurement signal of the Pt100 resistor is routed via a signal cable to the temperature transducer MACX MCR-EX-SL-RTD-I. In the measuring transducer, the temperature signal is converted into a standard signal, and the intrinsically safe and non-intrinsically safe circuits are isolated at the same time. The measuring transducer is an item of associated equipment of the "intrinsic safety Ex ia" protection type. It is installed in a control cabinet in the safe area. In this case, the circuit does not require any further electrical dimensioning work.

However, it is necessary to make sure that the sum of all cable/line capacitances and inductances in the intrinsically safe circuit does not exceed the data specified by the measuring transducer.



Example for case I

Comparison of the safety-related data from the hazardous area approval

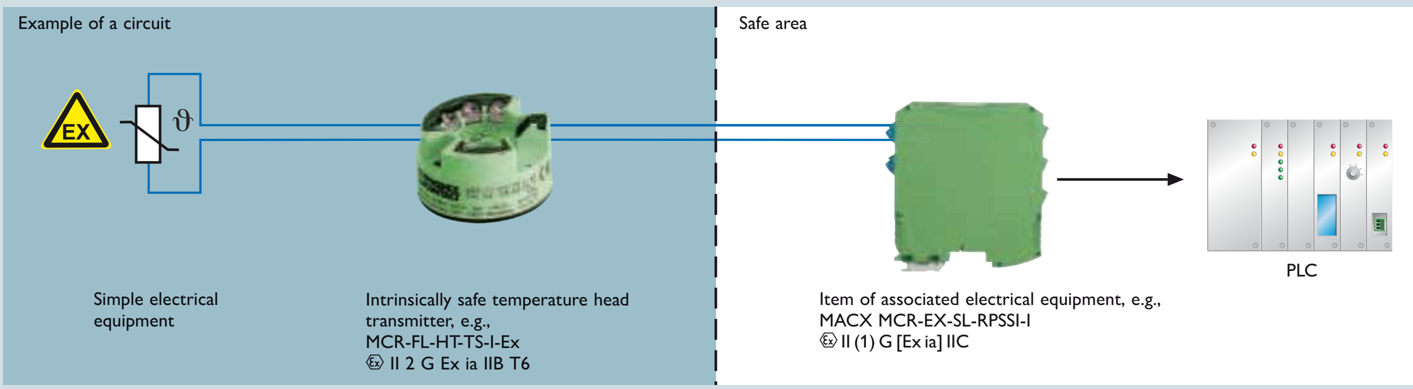
Pt100 resistor*	Cable/Line		Associated equipment	Example MACX MCR-EX-SL-RTD-I
		–	U_O	6 V
		–	I_O	6.3 mA
		–	P_O	9.4 mW
	+ C_C (140…200 nF/km approx.)	<	C_O	IIB = 6.9 µF IIC= 1.4 µF
	+ L_C (0.8…1 mH/km approx.)	<	L_O	IIB = 100 mH IIC = 100 mH

** Passive acc. to EN 60079-11*

Case II

In the second case, the conversion of the temperature signal to a standard signal takes place near the measuring point, in other words in the potentially explosive area. The temperature head transmitter MCR-FL-HT-TS-I-Ex is used for this. The standard signal is then routed to repeater power supply MACX MCR-EX-SL-RPSSI-I, which is installed in the safe area. The isolation of the intrinsically safe and non-intrinsically safe circuits takes place in the repeater power supply. As in the first case, no special conditions have to be met for the Pt100 resistor and the head transducer. The safety-relevant data of the electrical equipment, the intrinsically safe temperature head transmitter, and the repeater power supply as associated equipment must be compared.

The voltage, current, and energy of the repeater power supply must be lower than the permitted input values of the intrinsically safe temperature head transmitter. In addition, it is necessary to make sure that the sum of all capacitances and inductances in the intrinsically safe circuit does not exceed the data specified by the repeater power supply. This also includes the technical data of the cables and lines of the intrinsically safe circuit.



Example for case II

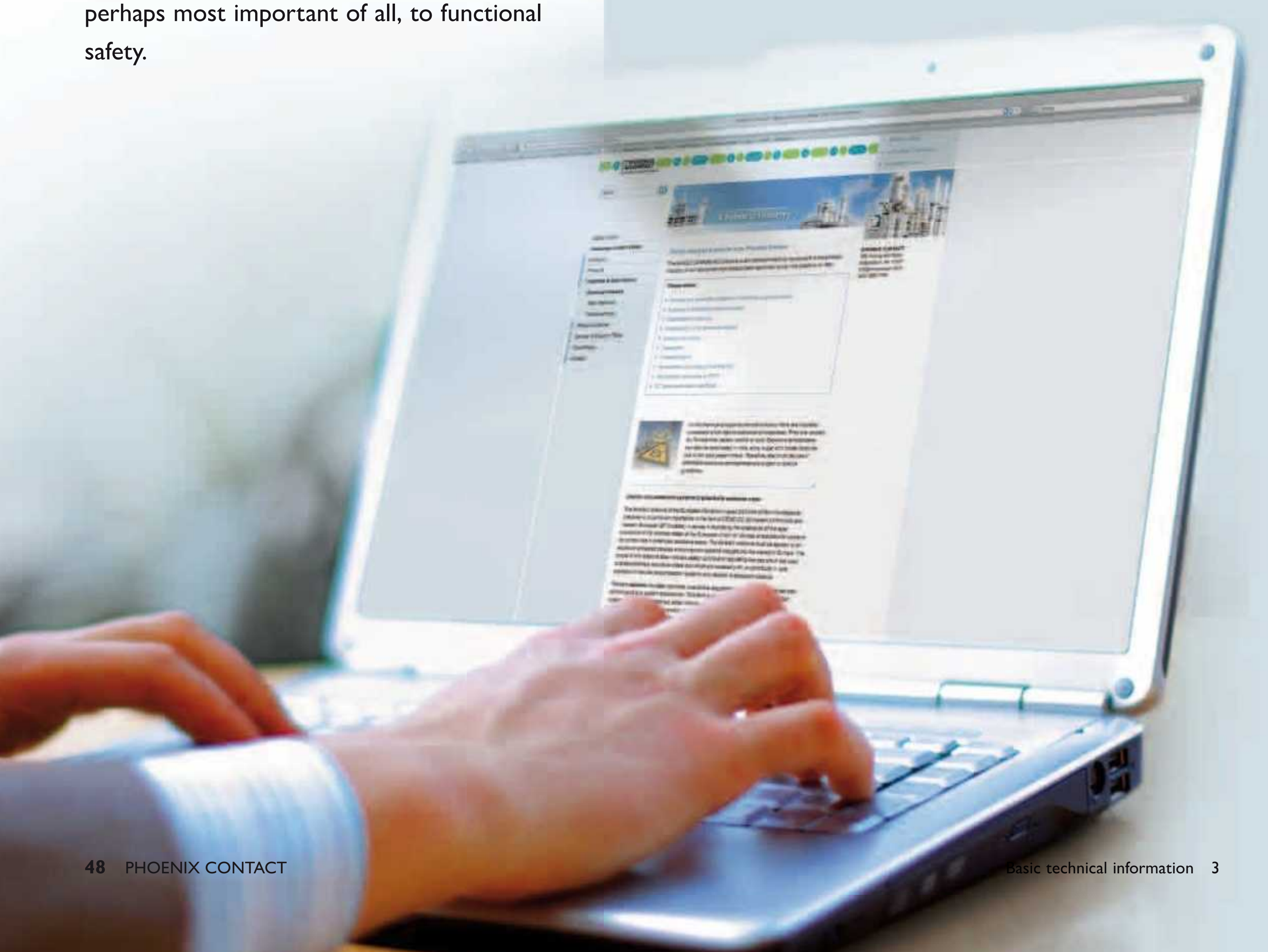
Comparison of the safety-related data from the hazardous area approval

Pt100 resistor*	Cable/ Line		Associated equipment	Example MCR-FL-HT-TS-I-Ex	Cable/ Line		Associated equipment	Example MACX MCR-EX-SL-RPSSI-I
		–	U_o	U_i = 30 V		>	U_o	25.2 V
		–	I_o	I_i = 100 mA		>	I_o	93 mA
		–	P_o	P_i = 750 mW		<	P_o	587 mW
	+ C_c	<	C_o	$C_i \approx 0$	+ C_c	<	C_o	IIC= 107 µF
	+ L_c	<	L_o	$L_i \approx 0$	+ L_c	<	L_o	IIC = 2 mH

** Passive acc. to EN 60079-11*

3 Basic technical information

It is important to be familiar with the fundamental relationships between MCR technology and explosion protection. However, there are also a range of other basic principles regarding MCR technology which, although not specifically related to explosion protection, are just as significant for it. This applies to IP degrees of protection, the method of operation of NAMUR sensors, and the transmission principle of the HART protocol, but perhaps most important of all, to functional safety.



NEMA classification

NEMA classification

NEMA	Application	Condition (based on NEMA standard 250)		IP degree of protection
1	Indoors	Protection against accidental contact and a limited amount of dirt	→	IP20
2	Indoors	Ingress of dripping water and dirt		
3	Outdoors	Protection against dust and rain; no damage when ice forms on the housing	→	IP64
3R	Outdoors	Protection against falling rain; no damage when ice forms on the housing	→	IP22
3S	Outdoors	Protection against dust, rain, and hail; external mechanisms remain operable when ice forms	→	IP64
4	Indoors or outdoors	Protection against splash-water, dust, and rain; no damage when ice forms on the housing	→	IP66
4X	Indoors or outdoors	Protection against splash-water, dust, and rain; no damage when ice forms on the housing; protected against corrosion	→	IP66
6	Indoors or outdoors	Protection against dust, water jets, and water during temporary submersion; no damage when ice forms on the housing	→	IP67
6P	Indoors or outdoors	Protection against water during longer submersion; protected against corrosion		
11	Indoors	Protection against dripping water; protected against corrosion		
12, 12K	Indoors	Protection against dust, dirt, and dripping, non-corrosive liquids	→	IP55
13	Indoors	Protection against dust and splash-water, oil, and non-corrosive liquids	→	IP65

Important notes:

- *The test conditions and requirements of the NEMA classification and IP protection (EN 60529) are not the same.*
- *IP degrees of protection cannot be converted into NEMA classifications.*

IP degree of protection (in accordance with EN 60529)

IP5

First characteristic numeral	Degrees of protection against access to dangerous parts and solid foreign bodies	
	Short description	**Definition**
0	Not protected	
1	Protected against touching dangerous parts with the back of the hand.	The access probe, a ball with a diameter of 50 mm, must be a sufficient distance from dangerous parts.
	Protected against solid foreign bodies with a diameter of 50 mm or above.	The object probe, a ball with a diameter of 50 mm, must not penetrate fully.*
2	Protected against touching dangerous parts with a finger.	The segmented test finger, 12 mm in diameter, 80 mm long, must be a sufficient distance from dangerous parts.
	Protected against solid foreign bodies with a diameter of 12.5 mm or above.	The object probe, a ball with a diameter of 12.5 mm, must not penetrate fully.*
3	Protected against touching dangerous parts with a tool.	The access probe, 2.5 mm in diameter, must not penetrate.
	Protected against solid foreign bodies with a diameter of 2.5 mm or above.	The object probe, 2.5 mm in diameter, must not penetrate at all*.
4	Protected against access to dangerous parts with a wire.	The access probe, 1.0 mm in diameter, must not penetrate.
	Protected against solid foreign bodies with a diameter of 1.0 mm or above.	The object probe, 1.0 mm in diameter, must not penetrate at all*.
5	Protected against access to dangerous parts with a wire.	The access probe, 1.0 mm in diameter, must not penetrate.
	Protected against dust.	The ingress of dust is not completely prevented, but dust may not enter in such an amount that the satisfactory operation of the device or safety is impaired.
6	Protected against access to dangerous parts with a wire.	The access probe, 1.0 mm in diameter, must not penetrate.
	Dust-proof.	No ingress of dust.

* *The complete diameter of the object probe must not pass through an opening of the housing.*

Note
If one characteristic numeral does not need to be specified, it must be replaced with the letter "X".
Devices that are identified with the second characteristic numeral 7 or 8 do not have to fulfill the requirements of the second characteristic numeral 5 or 6, unless they have a double identification (e.g., IPX6/IPX7).

4

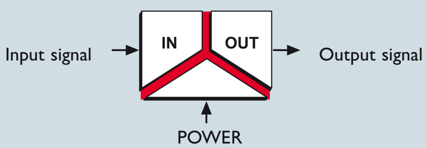
Second characteristic numeral	Degree of protection against water	
	Short description	**Definition**
0	Not protected	
1	Protected against dripping water	Vertically falling drops shall have no harmful effect.
2	Protected against dripping water if the housing is inclined at an angle of up to 15°.	Vertically falling drops shall have no harmful effect when the housing is inclined at an angle of up to 15° either side of the perpendicular.
3	Protected against spray-water.	Water that is sprayed at an angle of up to 60° either side of the perpendicular shall have no harmful effect.
4	Protected against splash-water.	Water that splashes against the housing from any direction shall have no harmful effect.
4K	Protected against splash-water with increased pressure.	Water that splashes against the housing under increased pressure from any direction shall have no harmful effect (only applies to road vehicles according to DIN 40 050, Part 9).
5	Protected against jet-water.	Water that is sprayed against the housing as a jet from any direction shall have no harmful effect.
6	Protected against powerful jet-water.	Water that is sprayed against the housing as a powerful jet from any direction shall have no harmful effect.
6K	Protected against powerful jet-water with increased pressure.	Water that is sprayed against the housing as a jet under increased pressure from any direction shall have no harmful effect (only applies to road vehicles according to DIN 40 050, Part 9).
7	Protected against the effects of temporary submersion in water.	Water may not penetrate in a harmful quantity when the housing is temporarily submerged in water under standard pressure and time conditions.
8	Protected against the effects of continuous submersion in water.	Water may not penetrate in a harmful quantity when the housing is submerged in water continuously under conditions to be agreed between the manufacturer and user. However, the conditions must be more stringent than those of characteristic numeral 7.
9K	Protected against water during high-pressure/jet-stream cleaning.	Water that is sprayed against the housing under extremely high pressure from any direction shall have no harmful effect (only applies to road vehicles according to DIN 40 050, Part 9).

3.1 MCR technology

Principles of signal transmission

Active isolation

3-way isolation



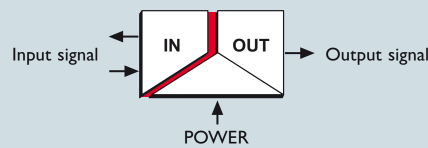
In the case of modules with this isolation method, all components that are connected to the input, output or power supply are protected from interference from each other.

All three directions (input, output, and power supply) are electrically isolated from one another accordingly.

The 3-way isolation provides electrical isolation between the measurement sensor and the controller as well as between the controller and the actuator.

On the input side, the modules need active signals. On the output side, they provide a filtered and amplified signal.

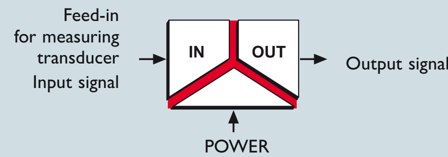
Input isolation



In the case of modules with this isolation method, the electronics connected on the output side (e.g., the controller) are to be protected from interference from the field. For this reason, only the input is electrically isolated from the output and the power supply which lie on the same potential.

On the input side, the modules need active signals (e.g., from measurement sensors). On the output side, they provide a filtered and amplified signal (e.g., from the controller).

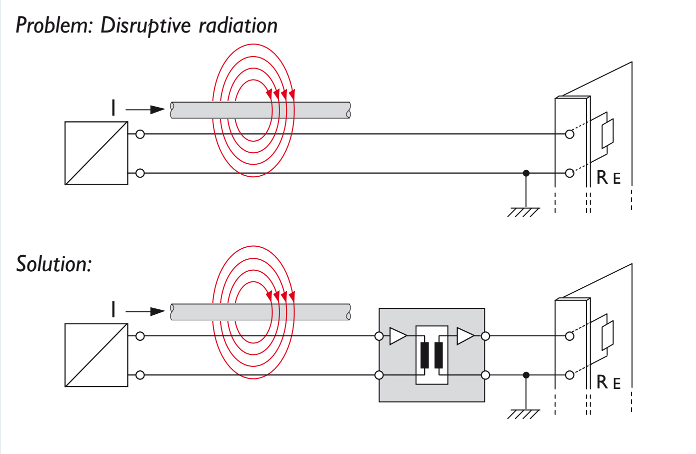
Repeater power supply

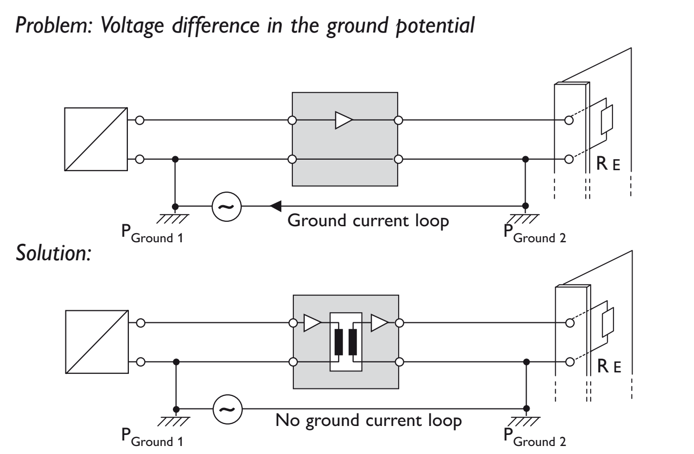


Repeater power supplies use the signal input side not only for measured value acquisition, but also to provide the necessary power to the passive measurement sensors connected on the input side.

On the output side, they provide a filtered and amplified signal (e.g., from the controller).

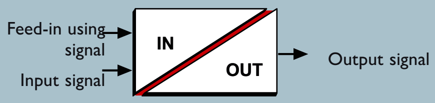
The isolation method used by these modules is input isolation.





Passive isolation

Passive isolation,
supplied on the input side

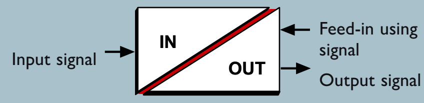


The modules receive the power needed for signal transmission and electrical isolation from the active input circuit.

On the output side, a conditioned current signal is provided to the controller or to actuators.

This passive isolation allows for signal conditioning (interruption of ground loops) and filtering without an additional power supply.

Passive isolation, supplied on the output side (loop-powered)

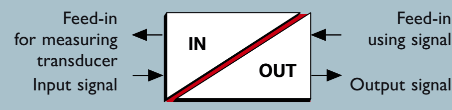


The modules receive the power needed for signal transmission and electrical isolation from the active output circuit, ideally from a PLC input board that supplies power.

On the output side, the loop-powered modules work with a 4...20 mA standard signal. On the input side, the passive isolator processes active signals.

When this isolation method is used, it is important to make sure that the active signal source connected on the output side (e.g., an active PLC input board) is able to supply the passive isolator with power, as well as operate its load.

Passive repeater power supply



The modules receive the power needed for signal transmission and electrical isolation from the active output circuit.

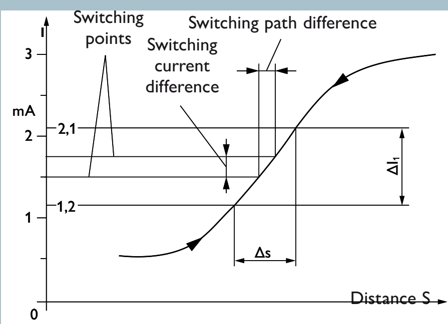
The passive repeater power supply also provides the power obtained from the output circuit to a passive measurement sensor connected on the input side.

The measurement sensor uses the power provided in this way to supply a signal, which is electrically isolated by the passive repeater power supply and made available on the output side.

For this reason, with a passive repeater power supply the signal and energy flows generally run in opposite directions to each other.

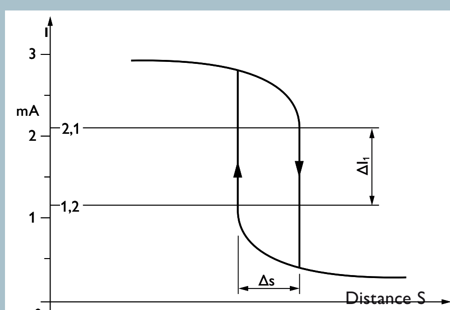
NAMUR sensor/switching amplifier

NAMUR sensors are a special kind of 2-wire proximity sensor, whose current output characteristic curve is defined in standard EN 60947-5-6. The evaluating electronics need to provide these sensors with a typical supply voltage of 8.2 V DC in order for them to operate. The "conductive" and "blocking" switching states have been defined for the proximity sensor, depending on whether the distance from the sensor to the object to be detected is over or under the switching threshold. This assignment can also be inverted if the application requires it.
According to the relevant standard, the "blocking" state has a defined sensor



Example of a continuous characteristic curve of a proximity sensor

current of 0.4 to 1.0 mA, while at least 2.2 mA and a minimum internal sensor resistance of 400 Ω are defined for the "conductive" state. These



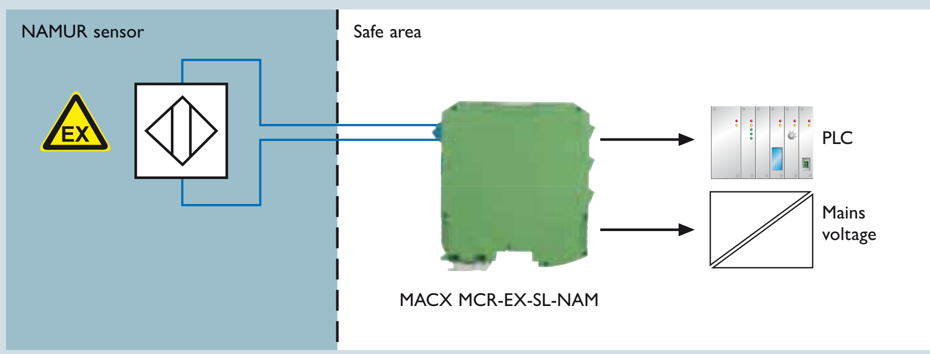
Example of a non-continuous characteristic curve of a proximity sensor

sensor currents must be evaluated by a downstream switching amplifier in accordance with the voltage/current diagram shown below.

Classification of proximity switches						
1st position/ 1 character	2nd position/ 1 character	3rd position/ 3 characters	4th position/ 1 character	5th position/ 1 character	6th position/ 1 character	8th position/ 1 character
Detection type	Mechanical installation conditions	Type and size	Switching element function	Output type	Connection method	NAMUR function
I = inductive **C** = capacitive **U** = ultrasound **D** = photoelectrically diffuse reflecting light beam **R** = photoelectrically reflecting light beam **T** = photoelectrically direct light beam	**1** = can be installed flush **2** = cannot be installed flush **3** = not specified	FORM (1 capital letter) **A** = cylindrical threaded sleeve **B** = smooth cylindrical sleeve **C** = rectangular with square cross-section **D** = rectangular with rectangular cross-section **SIZE** (2 numerals) for diameter or side length	**A** = N/O contact **B** = N/C contact **P** = can be programmed by user **S** = other	**D** = 2 DC connections **S** = other	**1** = integrated connecting cable **2** =plug-in connection **3** = screw connection **9** = other	**N** = NAMUR function

This table is an expansion of Table 1 in EN 60947-5-2.

NAMUR sensor in the field



Circuit design with a NAMUR sensor in the Ex area

NAMUR switching amplifier

NAMUR switching amplifiers allow the following signals and characteristics of NAMUR sensors to be evaluated:

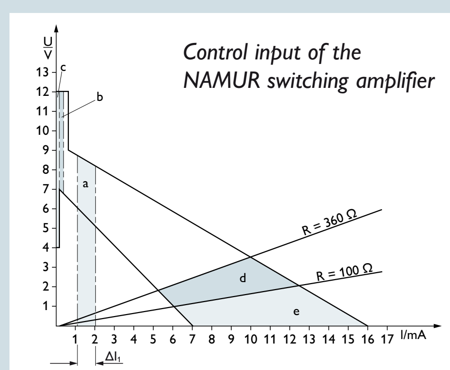
a Operating range for a change to the switching state ΔI_1: 1.2 mA to 2.1 mA

b Operating range for an interrupt in the control circuit ΔI_1: 0.05 mA to 0.35 mA

c Monitoring range for interrupt $I \leq 0.05$ mA

d Operating range for a short circuit in the control circuit ΔR: 100 Ω to 360 Ω

e Monitoring range for short circuit $R \leq 100$ Ω.



Smart-capable devices - HART protocol

In the process industry, a configuration must be performed or diagnostic data determined for a large number of analog field devices during commissioning and servicing, as well as during operation. To enable such communication with field devices, digital information is superimposed on the analog signal. For this purpose, all the devices involved must be Smart-capable.

In practice, the HART protocol has become established for this type of communication.

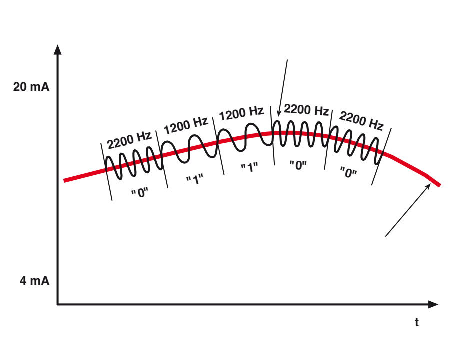
Since this technology is currently the most widely used, the "Smart" topic will be explained on this basis.

With the HART protocol, the transmission of the digital information is modulated to the analog 4 - 20 mA signal with the help of frequency shift keying (FSK).

In general, two possible operating modes are distinguished:

"Point-to-point" mode, in which communication is only possible with one field device connected in the 4 - 20 mA circuit, and "multi-drop" mode, in which up to 15 field devices in the circuit can be connected in parallel. These two operating modes basically differ in the fact that in "point-to-point" mode, the analog 4 - 20 mA signal can continue to be used in the usual way and transmits the desired process signal. In this case, additional data can also be transmitted in digital form. In "multi-drop" mode, a current signal of 4 mA is used in the field device as a carrier medium to transfer the exclusively digital information to and from the connected field devices.

Analog signal superimposed with digital HART signal

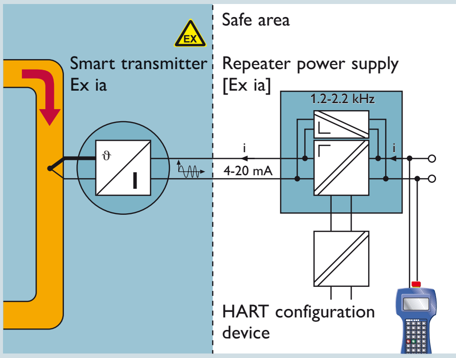


The devices can be connected in point-to-point mode as well as in multi-drop mode (with up to 15 parallel devices). In the case of point-to-point mode, the 4 - 20 mA signal remains available as a process signal as usual. Multi-drop mode requires an injected minimum current of 4 mA as a carrier for HART communication.

The aids that are used to implement this functionality depend on the technical infrastructure of the system installation. The diagnostics and configuration of the field devices can be carried out directly in the field at the terminals of the interface devices, with the help of a hand-held device. If the HART data is transmitted to higher-level engineering tools with HART multiplexers or via I/O modules of the control level, then they can also be used by asset management systems, for example.

Asset management systems offer the possibility of performing configuration and diagnostic functions automatically and additionally provide the technical framework for archiving the field device data (e.g., adjustable parameters).

Design with HART signal supply



Depending on the physical structure, the control level can also use HART communication to influence the field device (e.g., setpoint, measuring range change) from the controller or to request additional data (e.g., process signals).

As in standard installations (without HART communication), interface devices are used to connect the field devices (sensors and actuators) and the I/O level of the controller. To transmit the data that has been modulated to the analog 4 - 20 mA signal reliably and without interference, the interface devices used must be Smart-capable. This means that the HART signal must not be influenced at all during operation, e.g., by filters.

In the case of interface devices for signal conditioning with electrical isolation, the HART signal is decoupled in the interface device and transmitted separately.

The connected load in the circuit must also be taken into account, as the HART signal requires a terminating resistance of 250 Ω.

3.2 SIL principles (functional safety)

Standardized principles

Safety-related function for the Ex area

The term SIL (safety integrity level) is becoming more and more significant in the field of process engineering. It defines the requirements that a device or a system is expected to fulfill so that the failure probability can be specified. The aim is to achieve maximum possible operational reliability. If a device or system fails, a defined state is attained. Standard-based inspections are carried out to determine statistical probability.

Application of SIL on the basis of IEC 61508 and IEC 61511

The SIL standard is used for a wide range of sub-industries within the process industry, including chemicals, refineries, oil and gas production, paper manufacturing, and conventional power generation. In addition to functional safety, the Ex standards EN 60079-0 ff should also be used for systems in potentially explosive areas.

IEC 61508: Standard

"Functional safety of electrical/ electronic/programmable electronic safety-related systems"

This standard describes the requirements that the manufacturer has to bear in mind when producing devices or systems.

IEC 61511: Standard

"Functional safety. Safety instrumented systems for the process industry sector"

The IEC 61511 standard describes the requirements for installing and operating systems with functional safety.

Compliance with the standard is determined by operators, owners, and planners on the basis of safety plans and national regulations. In addition, the standard also describes the requirements for using a device in an application on the basis of its proven effectiveness (proven in use).

SIL inspection

The complete signal path must be observed during the SIL inspection. The example shows how estimates are made using average failure probabilities of individual devices in a typical safety-related application.

Table 2 of the IEC 61508-1 standard describes the relationship between the average failure probability and the attainable SIL. Here, the level required determines the overall budget for the sum of all PFD values.

Safety integrity level, SIL	Operating mode with a low demand rate (average probability of the specified function failing on demand)
4	$\geq 10^{-5}$ to $< 10^{-4}$
3	$\geq 10^{-4}$ to $< 10^{-3}$
2	$\geq 10^{-3}$ to $< 10^{-2}$
1	$\geq 10^{-2}$ to $< 10^{-1}$

Safety integrity level: Limit values for failures for a safety function which is operated in a mode with a low demand rate.

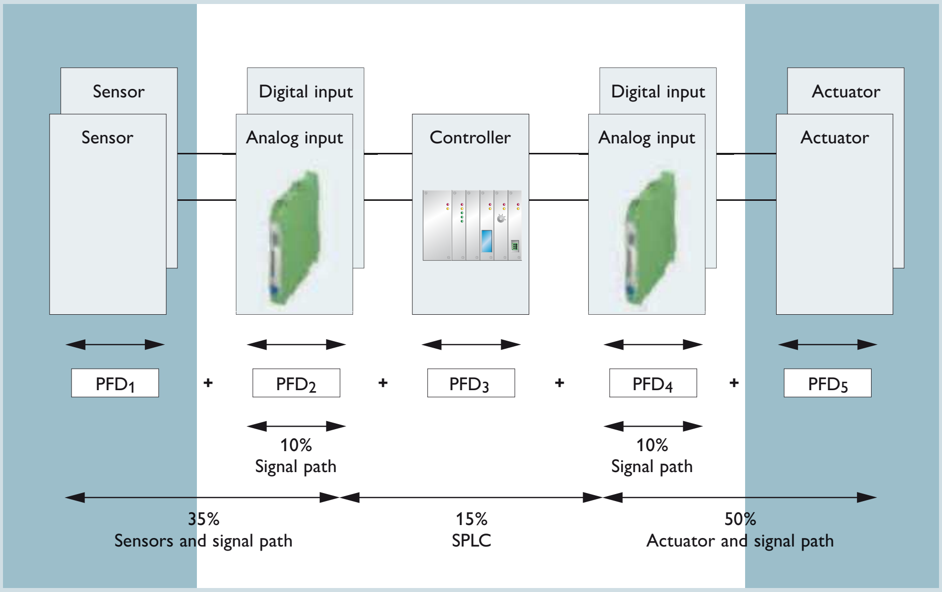
A system with a single-channel structure with a low demand rate has been taken as an example; the average PFD value lies between 10^{-3} and $< 10^{-2}$ for SIL 2.

Example:

Sensors and actuators are assembled in the field and are exposed to chemical and physical loads (process medium, pressure, temperature, vibration, etc.). Accordingly, these components have a high risk of failure, which is why 25% and 40% of the overall PFD are intended for the sensor and actuator respectively.

15% are designated for the failsafe controller and 10% for each of the interface modules. Neither comes into contact with the process medium and they are usually located in a protected control cabinet.

Typically, the values form the basis for a calculation.



Possible distribution of PFD values in a safety closed-loop control circuit

Overview of terms from the standards IEC 61508 and IEC 61511

SIL **Safety Integrity Level**

One of four discrete levels for the specification of requirements for the safety integrity of safety instrumented functions, which are assigned to the E/E/PE safety instrumented systems, where SIL 4 is the highest and SIL 1 the lowest level

EUC **Equipment Under Control**

Equipment, machines, devices or systems used in production, processing of materials, and transport

MTBF **Mean Time Between Failures**

The expected mean time between failures

PFD **Probability of Failure on Demand**

The probability of a failure on demand. (Low demand mode)

This describes the probability of a safety instrumented system failing to perform its function when required.

PFDavg **Average Probability of Failure on Demand**

The average probability of the function failing on demand

E/E/PES **Electrical/Electronic/ Programmable Electronic Systems**

This term is used for all electrical devices or systems, which can be used to execute a safety instrumented function. It includes simple electrical devices and all types of programmable logic controllers (PLC).

PFH **Probability of dangerous Failure per Hour**

Describes the probability of a dangerous failure occurring per hour. (High demand mode)

SFF **Safe Failure Fraction**

Describes the fraction of safe failures. This is the ratio of the rate of safe failures plus the rate of diagnosed or detected faults to the total rate of failures of the system.

SIF **Safety Instrumented Function**

Describes the safety instrumented functions of a system.

SIS **Safety Instrumented System**

An SIS (safety instrumented system) is made up of one or more safety instrumented functions. An SIL requirement is applicable for each of these safety instrumented functions.

3.3 Terms and abbreviations

Explosion protection terms

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", which 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 potentially explosive atmosphere.

Electrical equipment

All components, electric circuits or parts of electric circuits that are usually found 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 can also be seen in the square brackets and the round brackets of the identification. Associated equipment must be installed outside the potentially explosive area, provided that it does not comply with another suitable protection type.

Simple electrical equipment

An item of electrical equipment or a combination of components with a simple design, with precisely determined electrical parameters and that 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.
That means no voltage higher than the value of the associated U_i may be fed to this intrinsically safe circuit.
A possible addition of voltage must also be taken into account.
See also EN 60079-14, Annex B.

I_i = maximum input current

The highest current (peak value of the alternating current or direct current) that can be fed in through the connection elements of the intrinsically safe circuits without destroying the intrinsic safety.
That means no current higher than the value of the associated I_i may be fed to this intrinsically safe circuit.
A possible addition of current must be taken into account here as well.
See EN 60079-14, Annex 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.
That means that no intrinsically safe circuit with a higher power than P_i may be connected here.

Note on U_i, I_i, and P_i:

The EC-type examination 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 highest 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.
That means that U_o is the maximum non-load voltage that can be present at the terminal blocks at the maximum supply voltage in the case 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.
That means that I_o corresponds to the maximum possible short-circuit current at the connection terminal blocks, I_k.

P_o = maximum output power

The highest electrical power in an intrinsically safe circuit that can be taken from the item of equipment.
That means that when a sensor or actuator is connected to this intrinsically safe circuit, this power must be reckoned with, e.g., when heating up or with the load in relation to the associated temperature class.

C_i = maximum internal capacitance

Effective equivalent capacity at the connection elements for the internal capacitances of the item of equipment.

L_i = maximum internal inductance

Effective equivalent inductance at the connection elements for the internal inductances of the item of equipment.

C_o = maximum external capacitance

The maximum value of the capacitance in an intrinsically safe circuit that can be applied to the connection elements of the electrical equipment without destroying the intrinsic safety.
That means that this is the maximum value that all of the capacitances working outside of the items of 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 a linear ohmic current limitation, the value of C_o depends on U_o. See also EN 60079-11, Annex A, Table A2 and Fig. A2 and A3.

L_o = maximum external inductance

The maximum value of the inductance in an intrinsically safe circuit that can be applied to the connection elements of the electrical equipment without destroying the intrinsic safety.
That means that this is the value that all of the inductances working outside of the items of 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 a linear ohmic current limitation, L_o depends on I_o. See also EN 60079-11, Annex A, Fig. A4, A5, A6.

C_c = cable or line capacitance

Intrinsic capacitance of a cable or a 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

Intrinsic inductance of a cable or a line. This depends on the cable or line and is generally between 0.8 mH/km and 1 mH/km.

U_m = maximum true r.m.s. value of the AC voltage or maximum DC voltage

The maximum voltage that may 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.
That means that, for example, U_m = 250 V can be specified for the supply voltage and at the output U_m = 60 V. In accordance with EN 60070-14, 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 according to EN 60127 or according to the manufacturer's specification. This 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. Otherwise, the symbol "X" is added to the certificate number.

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PHOENIX CONTACT GmbH & Co. KG
32823 Blomberg, Germany
Phone: +49 5235 3-00
Fax: +49 5235 3-4 12 00
www.phoenixcontact.com

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