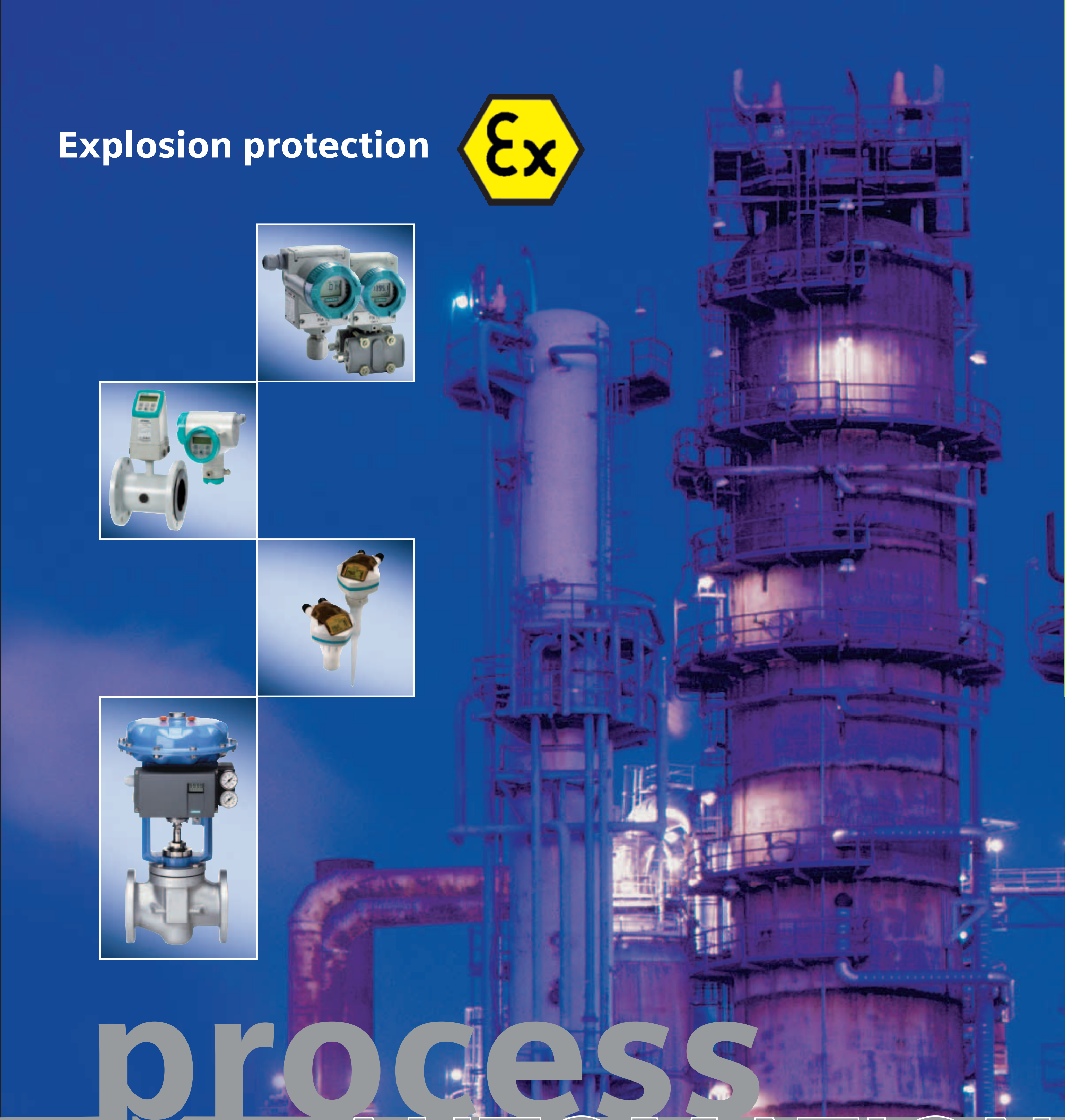
Explosion protection



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process AUTOMATION

SIEMENS

Foreword

Flammable and explosive substances in the form of gases, dusts or fibers occur in many industrial sectors, the most important of which are coal mining, chemicals and petrochemicals, the food industry and mills. The associated areas, plants or components are divided into zones with different degrees of danger depending on the frequency and duration of the occurrence of an explosive atmosphere. The users of such equipment are obliged by law to prevent the danger of explosion in the hazardous areas by using primary and secondary protective measures.

Three prerequisites are necessary for an explosion to occur: a flammable gas or dust, oxygen, and an ignition source. Primary explosion protection can be achieved e.g. by making the gas atmosphere inert. Secondary explosion protection covers the prevention of ignition sources. This means that the manufacturers of equipment used for process engineering must design and construct them such that they do not constitute an ignition source even when considering possible faults.

Explosion protection is regulated by law in most industrial countries. The European Union has issued a directive in this context – the so-called ATEX directive – which stipulates the use of type-tested explosion-proof equipment. The equipment manufacturers apply the harmonized explosion protection standards applicable in Europe, and request an EC type test. Following successful testing, the testing institute issues a corresponding certificate (ATEX certificate) which is a prerequisite for bringing the equipment into circulation in the EC. Similar regulations apply worldwide.

This brochure provides information on the topics of explosion protection, legal regulations, standards, degrees of protection, equipment identification etc. It is particularly appropriate for those who wish to obtain a rapid overview of the topic or a quick answer to a specific question. However, it should be remembered that the legal specifications and the standards are subject to continuous modification and adaptation to latest technical developments. The information provided in this brochure therefore corresponds to the state at the time of printing.

The Automation and Drives Group of SIEMENS AG manufactures and markets a comprehensive range of process instruments and analyzers. A large portion of the equipment is delivered as explosion-proof versions for which a wide variety of European and international approvals and certificates have been granted. These are a guarantee that the regulations applicable in target countries are observed, and also for safe operation of systems wherever they are used worldwide.

You can obtain information on our complete range and the existing product certificates on our Internet sites at

www.siemens.com/processinstrumentation

or by using our online ordering system, the A&D Mall, at

www.siemens.com/automation/mall

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1 Directives and standards

1.1 Legal principles of explosion protection

Explosion protection is legally regulated worldwide by the governments of the individual states. Country-specific differences in the technical requirements and requested approvals for explosion-proof devices are a significant hindrance to the trade of globally operating manufacturers, and necessitate high development and approval overheads.

It has been the interest of leading industrial nations for a long time already to eliminate these hindrances by harmonization of the relevant technical standards, and to implement uniform safety standards at the same time. Within the European Community, the harmonization process in the explosion protection sector has been largely completed in the meantime. At the international level, the IEC is attempting to reach the goal "One test and one certificate worldwide" by introducing the so-called IECEx scheme.

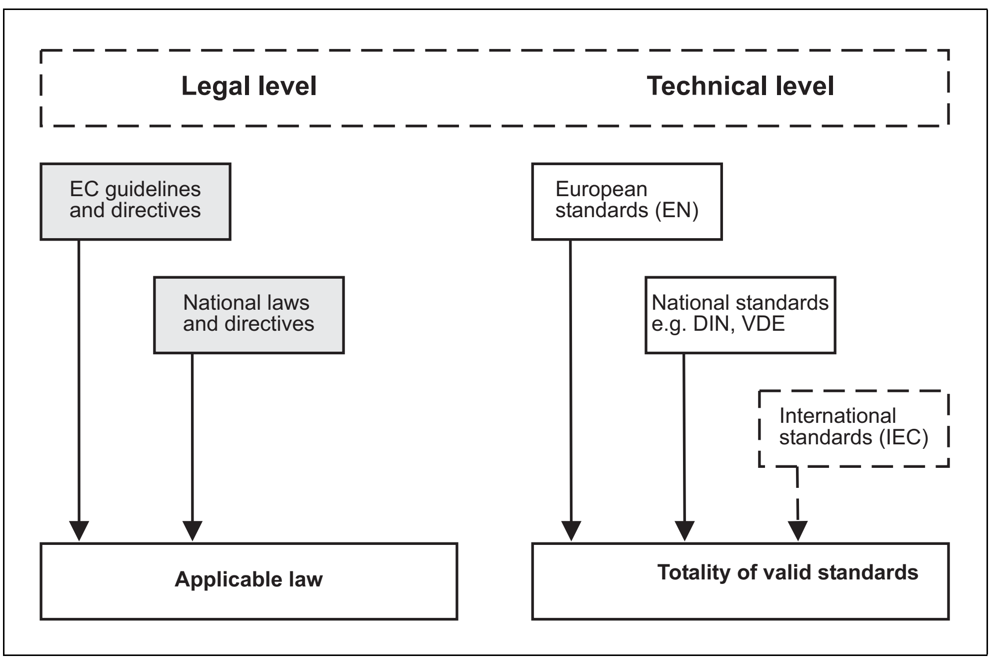


Fig. 1 Legal considerations of explosion protection in Europe

1.1.1 EC guidelines

Explosion protection is regulated in the European Community by directives and laws. The basis of these EC activities is the so-called "New concept" whose concern is formulated as follows: "The free movement of merchandise is a corner pillar of the domestic market. To achieve this goal, mechanisms have been created whose objective is to avoid new hindrances to trade, to achieve mutual recognition and to implement technical harmonization."

Abbreviation	Complete title	Directive No.	Valid from	End of transition period
Low-voltage directive	Directive of the council dated February 19, 1973, for alignment of the legal regulations of the member states concerning electrical equipment for use within certain voltage limits	73/23/EEC	19.08.74	01.01.97
Modification		93/68/EEC	01.01.95	01.01.97
EMC guideline	Directive of the council dated May 3, 1989, for alignment of the legal regulations of the member states concerning electromagnetic compatibility	89/336/EEC	01.01.92	31.12.95
Modification		92/31/EEC	28.10.92	---
Modification		93/68/EEC	01.01.95	31.12.94
Machine guideline	Directive of the European Parliament and the council dated June 22, 1998, for alignment of the legal and administrative regulations of the member states concerning machines	98/37/EC (based on 89/392/EEC)	01.01.93	31.12.94
EX-RL (ATEX 100a)	Directive of the European Parliament and the council dated March 23, 1994, for alignment of the legal regulations of the member states concerning equipment and protective systems for normal use in hazardous areas	94/9/EC	01.03.96	30.06.03
Pressure equipment directive	Directive 97/23/EC of the European Parliament and the council dated May 29, 1997, for alignment of the legal regulations of the member states concerning pressure equipment	97/23/EC	29.11.99	29.05.02
ATEX 137 (old: ATEX 118a)	Minimum regulations for improvement of health protection and safety of employees who could be endangered by potentially explosive atmospheres	1999/92/EC	16.12.99	30.06.03

Table 1 Important EC directives for process equipment

The objective of the EC on the one hand is therefore to provide equal chances for all vendors within the EC domestic market, and on the other hand to produce uniform safety standards for all users of technical systems and equipment. Electrical equipment for use in hazardous areas must therefore possess an EC-type examination certificate (Zones 0 and 1). Corresponding systems and equipment are therefore classified as systems requiring supervision and may only be equipped with approved devices. Furthermore commissioning, modifications and regular safety inspections must be carried out or accepted by approved institutions or associations. The EC directives constitute the legal framework, and have been issued as compulsory for all EC member states.

Low-voltage directive 73/23/EEC and 93/68/EEC

The low-voltage directive includes safety requirements for electrical equipment. It is currently being revised and adapted to a number of new developments. Whereas the previous version specified the range of applicability as equipment with voltages above 75 V DC or 50 V AC, the new version applies to voltages starting at 0 V, i.e. now covers all electrical devices including those for battery operation.

Explosion protection directive 94/9/EC

The directive 94/9/EC, better known as the ATEX directive (ATEX 100a), regulates the manufacture and bringing into circulation of devices and protective systems for use in hazardous areas. The safety aspects are based on the "Fundamental safety and health requirements for the design and construction of devices and protective systems for normal use in hazardous areas" according to Appendix II. The directive stipulates an EC-type examination certificate with a corresponding test certificate (Ex certificate) for electrical equipment of categories 1 and 2 (see Section 5.1).
A manufacturer's declaration (EC declaration of conformity) specifying observation of the guideline, if applicable with application of specific standards, is requested for equipment of category 3.

Directive 1999/92/EC (ATEX 137)

The directive 1999/92/EC, also known as ATEX 137, formulates minimum requirements for the safety and health protection of employees at places of work which could be endangered by potentially explosive atmospheres. The directive is therefore mainly applicable for the users of hazardous plants and equipment. The contents of this directive are reflected in German law in the regulation for safe working conditions.

1.1.2 National laws and directives

Explosion protection directive ExVO

The directive 1999/92/EC, also known as ATEX 137, formulates minimum requirements for the safety and health protection of employees at places of work which could be endangered by potentially explosive atmospheres. The directive is therefore mainly applicable for the users of hazardous plants and equipment. The contents of this directive are reflected in German law in the regulation for safe working conditions.

Regulation for safe working conditions BetrSichV

On the other hand, the ATEX 137 (RL - 1999/92/EC) only includes "Minimum requirements for improving the health protection and safety of employees at places of work which could be endangered by potentially explosive atmospheres" meaning that each EC state can issue its own regulations. In the Federal Republic of Germany, the contents of the directive are implemented in the regulation for safe working conditions. With the intention of simplifying legal aspects, the contents of several previous directives were combined in the BetrSichV at the same time.

These are the following from the explosion protection sector:

- Directive concerning electrical equipment in hazardous areas (ElexV)
- Acetylene directive
- Directive concerning flammable liquids

These directives were canceled with the coming into force of the BetrSichV on.

Explosions protection directives (EX-RL) of the trade associations

In the "Guidelines for avoidance of danger by potentially explosive atmospheres with examples" of the chemical trade association, specific information is provided on the dangers in hazardous areas, and measures shown to avoid or reduce them. The examples are particularly important and show in detail how these measures can be applied in various hazardous process plants from highly different industrial sectors. Important suggestions and estimations of risk are therefore available to planners and users of such process plants or of comparable plants. The EX-RL directives do not have a legal status, but should be understood as important recommendations which can be used as support to clarify legal aspects in the event of a claim.

Abbreviation	Complete title	Valid from
Equipment safety law GSG	Law for technical equipment	Permanently supplemented
Explosion protection directive ExVO	Directive for the bringing into circulation of devices and protective systems for hazardous areas - explosion protection directive (ExVO; 11.GSGV)	12.12.96
Regulation for safe working conditions BetrSichV	Regulation for legal agreement concerning safety and protection of health when providing and using equipment at the place of work, concerning safety when operating plants requiring supervision, and organization of industrial health and safety standards.	03.10.02
Explosion protection regulations Ex-RL	Directives and rules from the trade associations for safety and health at work - BGR 104: explosion protection regulations with examples	(release July 2000)

Table 2 Laws, directives and regulations concerning explosion protection in the Federal Republic of Germany

1.2 Standards

A large number of technical standards exist worldwide for the sector of explosion protection. The standards are also subject to continuous modification. This is the result of adaptation to technical advancements as well as increased safety demands in the community. Parallel to this, the efforts towards international harmonization are making a contribution towards achieving uniform safety standards as far as possible worldwide, with the associated elimination of trade hindrances.

1.2.1 EC standards

The explosion protection standards applicable in the European Community are produced on the basis of the EC guidelines under the directive of CENELEC (European committee for electrotechnical standardization). CENELEC members are the national committees of the member states. Since standardization at the international level has greatly increased in significance in the meantime as a result of the high dynamics in the IEC, CENELEC has decided to only pass standards in the so-called parallel procedure with the IEC. This basically means that almost all European standards in the electrotechnical sector are being produced or revised as harmonized EN standards on the basis of IEC standards. These are mainly the standards of the EN 60079-xy series for the explosion protection sector.

The numbers of the harmonized European standards have the following format:

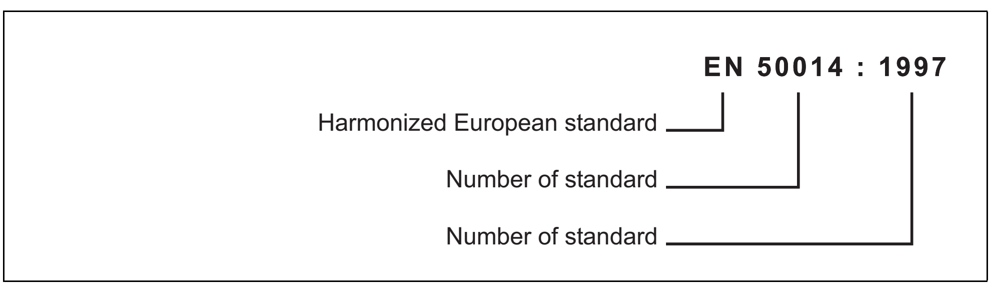


Fig. 2 Number format for harmonized European standards

Modifications issued as supplements to the basic standard are identified by subsequent letters "A" with consecutive number, e.g. A1.

1.2.2 National standards

Own national standards also exist in most EC member states and can be used in the respective country parallel to the applicable EN standards. In the Federal Republic of Germany, these are the DIN standards and the VDE regulations. However, in the explosion protection sector, extensive harmonization has already taken place, and most standards now also exist in a version as "DIN EN...." which have generally been imported into the VDE regulations. DIN EN standards are identical to the corresponding EN standards, where special national features, e.g. concerning areas of applicability etc., are formulated in a national foreword.

European standard	German standard	Title
EN 1127	DIN EN 1127-1	Potentially explosive atmospheres - explosion protection - Part 1: fundamentals and methods
EN 50 014	DIN EN 50 014, VDE 0170/0171 Part 1	Electrical equipment for hazardous areas: general specifications
EN 50 015	DIN EN 50 015, VDE 0170/0171 Part 2	Oil immersion "o"
EN 50 016	DIN EN 50 016, VDE 0170/0171 Part 3	Pressurized enclosure "p"
EN 50 017	DIN EN 50 017, VDE 0170/0171 Part 4	Sand filling "q"
EN 50 018	DIN EN 50 018, VDE 0170/0171 Part 5	Flameproof enclosure "d"
EN 50 019	DIN EN 50 019, VDE 0170/0171 Part 6	Increased safety "e"
EN 50 020	DIN EN 50 020, VDE 0170/0171 Part 7	Intrinsic safety "i"
EN 60 079-15	DIN EN 50 021, VDE 0170/0171 Part 8	Type of protection "n"
EN 50 028	DIN EN 50 028, VDE 0170/0171 Part 9	Encapsulation "m"
EN 50 039	DIN EN 50 039, VDE 0170/0171 Part 10	Electrical equipment for hazardous areas; intrinsically-safe electrical systems "i"
EN 50 284	DIN EN 50 284, VDE 0170/0171 Part 12	Special requirements concerning design, testing and identification of electrical equipment of equipment group II, category 1 G
EN 13 463-1	DIN EN 13 463-1	Non-electrical equipment for use in hazardous areas, Part 1: fundamental methods and requirements
EN 50 281-1-1	DIN EN 50281-1-1, VDE 0170/0171 Part 15-1-1	Electrical equipment for use in areas with flammable dust, Part 1-1: electrical equipment with protection by enclosure
EN 60079-10	DIN EN 60079-10, VDE 165 Part 101	Electrical equipment for areas with explosive gas atmosphere, Part 10: organization of hazardous areas
EN 60079-14	DIN EN 60079-14, VDE 165 Part 1	Electrical equipment for hazardous areas, Part 14: electrical equipment in hazardous areas (except pits)
EN 60079-17	DIN EN 60079-17, VDE 0165 Part 10	Electrical equipment for areas with explosive gas atmosphere, Part 17: testing and maintenance of electrical equipment in hazardous areas (except pits)
EN 61010-1	DIN EN 61010-1, VDE 0411 Part 1	Safety regulations for electrical measuring, control and laboratory equipment, Part 1: general requirements
EN 60950	DIN EN 60950, VDE 0805	Safety of IT equipment including electrical office machines

Table 3 Harmonized European standards for explosion protection

1.2.3 International standards

IEC

At the international level, standards for explosion protection are issued by the IEC (International Electrotechnical Commission). The technical committee TC31 is responsible. Standards for explosion protection are included in the IEC 60079-x series (previously IEC 79-x). The x represents the number of the individual technical standard, e.g. IEC 60079-11 for intrinsic safety.

USA

The highest supervisory authority in the USA is the OSHA (Occupational Safety and Health Administration) which issues the legal regulations for industrial health and safety. Standards are drawn up by various organizations on the basis of these. Explosion protection is regulated within the National Electrical Code (NEC), a code issued by the National Fire Protection Association (NFPA) in agreement with the American National Standard Institute (ANSI). Based on this, various test organizations issue their own standards, e.g. UL (Underwriters Laboratories), FM (also FMRC - Factory Mutual Research Corporation).

Important for the classification of explosion protection are Articles 500 and 505 of the NEC, where the former regulates the requirements of the conventional Ex classification (Class/Division model) and the latter the requirements for the new zone model based on European and IEC directives. Equipment can be certified in parallel according to both models.

Canada

The structure in Canada is comparable with that in the USA. Based on the CEC (Canadian Electrical Code), the Canadian Standards Association (CSA) issues standards which are the basis for corresponding equipment approvals. Canada also uses a conventional Class/Division model for explosion protection, as well as the new international zone system, and parallel certification is also possible.

Subject	Interna-tional	Europe	USA			Canada		
			FM	UL	ANSI/ISA	Ex Zone model	Ex Class/ Division model	Other
Ex: general specifica-tions	IEC 60 079-0	EN 50 014	FM 3600		ANSI/ ISA-S12.0.01	CSA 79-0-95		
Oil immer-sion "o"	IEC 60 079-6	EN 50 015		UL2279, Pt.6	ANSI/ ISA-S12.26.01	CSA-E79-6		
Pressur-ized enclo-sure "p"	IEC 60 079-2	EN 50 016	FM 3620	(NFPA4 96)		CSA-E79-2	CSA TIL. E 13 A	
Sand filling "q"	IEC 60 079-5	EN 50 017		UL2279, Pt.5	ANSI/ ISA-S12.25.01	CSA-E79-5		
Flame-proof enclo-sure "d"	IEC 60 079-1	EN 50 018	FM 3615	UL2279, Pt.1 UL1203	ANSI/ ISA-S12.22.01	CSA-E79-1	CSA C22.2 No.30	
Increased safety "e"	IEC 60 079-7	EN 50 019		UL2279, Pt.7	ANSI/ ISA-S12.16.01	CSA-E79-7		
Intrinsic safety "i"	IEC 60 079-11	EN 50 020	FM 3610	UL2279, Pt.11 UL 913	pr ANSI/ ISA-S12.02.01	CSA-E79-11	CSA C22.2 No.157	
Type of protection "n"	IEC 60 079-15	EN 60 079-15	FM 3611	UL2279, Pt.15	pr ANSI/ ISA S12.12.01	CSA-E79-15	CSA C22.2 No.213	
Encapsula-tion "m"	IEC 60 079-18	EN 50 028		UL2279, Pt.18	ANSI/ ISA-S12.23.01	CSA-E79-18		
Zone 0	IEC 60 079-26	EN 50 284						
Electrical safety	IEC 61010	EN 61010			ANSI/ ISA-82.02.01			CAN/ CSA-C22.2 No. 1010.1

Table 4 Comparison of international and European standards

1.2.4 NAMUR

The NAMUR recommendations are extremely important in the process engineering sector in the Federal Republic of Germany, and also in other European countries to a certain extent. NAMUR (standards committee for instrumentation and control engineering) is an association comprising process engineering users with the objective of defining practice-oriented safety standards, solutions and systems for applications in the chemical and pharmaceutical industries by influencing both the standards committees and the manufacturers of process equipment. Towards this end, NAMUR issues recommendations on practically all technical topics of interest to this circle of users, which are published as the so-called NAMUR recommendations or NAMUR working sheets with a consecutive number NE ***/NA ***.

2 Certificates, certification procedures and product conformity

2.1 European Community

2.1.1 EC certificate of conformity and CE marking

Products put into circulation for the first time within the European Community are subject to the so-called EC directives. The manufacturer (or the vendor bringing into circulation) is obliged to observe all EC directives applicable to the respective product. He confirms this in the EC certificate of conformity, a document which must be enclosed with each supplied device. The certificate of conformity should list all applied EC directives and, if applicable, the harmonized EN standards which are complied with. The issuer of the certificate of conformity is the manufacturer or the vendor of the device.

The associated device must be identified by the CE symbol on the type plate. The CE symbol therefore indicates that the identified device complies with all(!) appropriate European directives and not - as sometimes incorrectly assumed - only indicates observation of the EMC guideline!

2.1.2 EC-type examination certificate

The ATEX directive 94/9/EC stipulates a type examination for explosion-proof electrical devices of categories 1 and 2 (see Section 2.1.1). The manufacturer must provide all technical documents required for the test, and also specimen devices if applicable, to a so-called Notified Body. Following successful testing, an EC-type examination certificate is issued on which all information and parameters compulsory for use in hazardous areas are certified. The EC-type examination certificate contains all information required for explosion protection, and is the basis for the operation and connection of several electrical devices in the hazardous zones 0 and 1.

Each certificate has its own number with the following format:

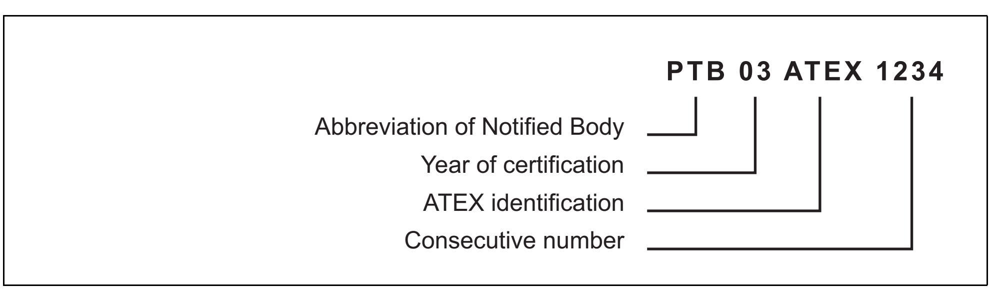


Fig. 3 Format of certificate number

A following "X" is the identification for "Particular information for operation" in the EC-type examination certificate. A following "U" identifies a partial certification for products which are not used on their own but only as a safety-relevant part of explosion-proof devices.

According to the ATEX directive, an EC-type examination certificate is not envisaged for devices of category 3 as specified for use in Zone 2 (see Section 4.1), and the issuing thereof is not permissible either. Instead of this, the manufacturer should issue a declaration (EC certificate of conformity) confirming compliance with the ATEX directive and the harmonized standards applicable to these devices. However, plant users occasionally request a test certificate from an independent organization for these devices as well, or the manufacturer wishes to carry out such a test for self-protection. Various test companies provide their own certification in such cases following testing of the devices which then have a non-official name, e.g. conformity statement or similar. It should again be explicitly mentioned that this is not envisaged in the ATEX guideline. On the contrary, one has intentionally left the device manufacturers with more freedom for own responsibility in order to simplify access to markets.

2.1.3 Testing stations in the EC

Notified Body	Country	No.
TÜV-Österreich 1010 Wien	AT	0408
EXAM-BBG Prüf- und Zertifizier GmbH (DMT until 30.04.03) 44809 Bochum	D	0158
IBEXU - Institut für Sicherheitstechnik GmbH 09599 Freiberg	D	0637
Physikalisch-Technische Bundesanstalt (PTB) 38116 Braunschweig	D	0102
TÜV Anlagentechnik GmbH, Gruppe Rheinland/Berlin/Bran-denburg 51105 Cologne	D	0035
TÜV Nord Cert GmbH & Co KG 30519 Hanover	D	0032
TÜV Product Service GmbH 80339 Munich	D	0123
ZELM Ex Prüf- und Zertifizierstelle 38124 Braunschweig	D	0820
UL International DEMKO 2730 Herlev	DK	0539
Laboratoire Central des Industries Electriques (LCIE) 9226 Fontenay-aux-Roses	F	0081
CESI Centro Electrotecniso Sperimentale Italiano 20134 Milan	I	0722
Societe Nationale de Certification S.A.R.L. (SNCH) 5230 Sandweiler	L	0499
NEMKO AS 0314 Oslo	N	0470
KEMA Quality B.V. 6800 ET Arnheim	NL	0344
ITS Testing and Certification Ltd. KT22 7SB Leatherhead	UK	0359
SIRA Certification Servicesira Test & Cert. Ltd. BR7 5EH Chislehurst - Kent	UK	0518

Table 5 Notified Bodies (testing stations) in the EC (extract)

One or more approved testing stations - referred to in the EC language as Notified Bodies - exist in practically all EC countries. These are selected by the member states following evaluation of their professional competence and establishment of their independence and neutrality, and published by the Commission in the European Community circular.

The table lists a selection of the most important testing stations. The complete and up-to-date list can be found on the EC's Internet site (URL: http://europa.eu.int/comm/enterprise/newapproach).

2.2 North America

2.2.1 USA

Tested, explosion-proof electrical equipment is also required in the USA for operation in hazardous areas. Approved test organizations (NRTLs - National Recognized Test Laboratories), such as e.g. FM, UL, CSA etc., test the devices for compliance with the corresponding directives and standards and provide an Approval Report for operation in hazardous locations. FM has additionally issued a Certificate of Compliance in recent years. This is an extract from the Approval Report and only contains the data and information important for the user.

The test organizations issue a label which must be attached to the equipment. The approved test organization have equal rights. However, dependent on the federal state or town in which the plant will operate, an FM or UL-Approval will specially be requested.

2.2.2 Canada

The conditions in Canada are comparable with those in the USA. The CEC (Canadian Electrical Code) applies here, and testing is carried out according to CSA standards. Recognized testing authorities include CSA, UL, FM and a number of others. As in the USA, devices with approval for hazardous locations are also required in Canada for operation in hazardous areas. In addition, the standard Safety Approval ("CSA Approval") also applies here which certifies compliance with electrical safety standards.

2.3 Russian Federation

The Russian Federation also has its own certification system for electrical equipment. Each device requires its own introduction certificate and the so-called GOST-R certificate which certifies the electrical safety. Explosion-proof devices are additionally issued with a special explosion protection certificate. Meteorological certificates are also occasionally required by Russian users. All these certificates can be applied for at the Russian approval authority GOSSTANDARD. With respect to explosion protection, it is generally sufficient to provide the test reports from renowned EC testing stations without having to carry out own technical tests again.

2.4 Other states

Most of the Eastern bloc states currently still require their own certificates, but do accept the test reports of Notified Bodies as EC testing stations. The same applies to Asian states such as China and Korea. Australia has its completely separate certification system which, however, is largely based on IEC standards in the meantime. Switzerland is also a special case since it is not an EC member but accepts the EC-type examination certificates by law in the explosion protection sector.

2.5 IECEx scheme

The work of the IECEx scheme has progressed so far that certification for explosion-proof devices is now possible on the basis of the IEC standards and with issuing of a corresponding IECEx certificate. The objective is worldwide acceptance of the IEC certificate so that manufacturers will not require any further approvals for the complete global market in the future. Most states worldwide, including the EC, have declared this intention, but the required statutory adaptations have not yet been carried out.

3 Secondary explosion protection

3.1 Zone classification

Hazardous areas are classified in zones. The classification depends on the time-related and local probability of the presence of a dangerous explosive atmosphere. Equipment for permanently hazardous areas (Zone 0) are subject to higher demands, equipment for less hazardous areas (Zone 1, Zone 2) are subject to lower demands.

In North America (USA/Canada), the hazardous areas are divided into Divisions (conventional system, in USA according to NEC 500) or Zones (new system oriented according to IEC, in USA according to NEC 505).

3.1.1 Zone classification according to CENELEC and IEC

In Europe, the hazardous areas are classified into zones depending on the degree of danger. The equipment is divided into categories corresponding to its purpose of use in different zones (guideline 94/9/EC). The category thus indicates the zone in which the respective equipment may be used.

Substance	Zone	Equipment category
Gases Vapors	**Zone 0** Areas in which dangerous concentrations of flammable gases/ vapors are present **continuously** or **long-term**.	1G
	Zone 1 Areas in which dangerous concentrations of flammable gases/ vapors are present **occasionally**.	2G, 1G
	Zone 2 Areas in which dangerous concentrations of flammable gases/ vapors are present **rarely** and then only **briefly**.	3G, 2G, 1G
Dusts	**Zone 20** Areas in which dangerous concentrations of flammable dusts are present **continuously** or **long-term**.	1D
	Zone 21 Areas in which dangerous concentrations of flammable dusts are present **occasionally**.	2D, 1D
	Zone 22 Areas in which dangerous concentrations of flammable dusts of present **rarely** and then only **briefly**.	3D, 2D, 1D

Table 6 Zones according to IEC/CENELEC for gases, vapors and dusts

3.1.2 Zones according to NEC 505

The National Electrical Code NEC 505 is used in North America. NEC 505 takes into account the new IEC definitions, i.e. the hazardous areas are divided into zones. With respect to the assignment of substances, NEC 505 only defines Class I for gases/vapors.

Substance	Zone
Class I Gases Vapors	Zone 0 Areas in which dangerous concentrations of flammable gases/vapors are present **continuously** or **short-term** under normal operating conditions.
	Zone 1 Areas in which dangerous concentrations of flammable gases/vapors are present **occasionally** under normal operating conditions.
	Zone 2 Areas in which dangerous concentrations of flammable gases/vapors are probably **not** present under normal operating conditions.

Table 7 Zones according to NEC 505 for gases/vapors

3.1.3 Divisions according to NEC 500

The conventional system in North America according to NEC 500 divides the hazardous areas into Divisions. The assignment of substances is divided according to Class I, II, III.

Substance	Zone
Class I Gases Vapors	**Division 1** Areas in which dangerous concentrations of flammable gases/vapors are present **continuously** or **occasionally** under normal operating conditions.
	Division 2 Areas in which dangerous concentrations of flammable gases/vapors are probably **not** present under normal operating conditions.
Class II Dusts	**Division 1** Areas in which dangerous concentrations of flammable dusts are present **continuously** or **occasionally** under normal operating conditions.
	Division 2 Areas in which dangerous concentrations of flammable dusts are probably **not** present under normal operating conditions.
Class III Fibers Fluff	**Division 1** Areas in which dangerous concentrations of flammable fibers and fluff are present **continuously** or **occasionally** under normal operating conditions.
	Division 2 Areas in which dangerous concentrations of flammable fibers/fluff are probably **not** present under normal operating conditions.

Table 8 Zones according to NEC 500 for gases/vapors, dusts and fibers/fluff

3.2 Types of protection

3.2.1 Types of protection for gas explosion protection

The types of protection define design-related and circuit-related measures for equipment for use in hazardous areas. These measures prevent the ignition of an ambient explosive atmosphere by sparks or an excessive temperature rise.

Type of protection	Symbol	Description
Increased safety	e	Prevention of ignition sources through special insulation requirements, observation of distances, temperature requirements etc. Mainly used for connection elements, motors etc.
Flameproof enclosure	d	Parts which could ignite are enclosed in a housing which is designed such that transfer of the explosion to the environment is prevented in the event of an ignition.
Pressurized enclosure	p	The penetration of an explosive atmosphere into the equipment is prevented by purging with inlet gas which is kept at a slight overpressure.
Intrinsic safety	i	The ignition of an explosive atmosphere is prevented by limiting the voltage, current, power and temperature.
Oil immersion	o	The equipment is immersed in oil, thus preventing contact with an explosive atmosphere.
Sand filling	q	The equipment housing is filled with a fine-grained material, usually quartz sand, so that any sparks cannot ignite an ambient explosive atmosphere.
Encapsulation	m	Parts which could ignite an explosive atmosphere are embedded in a sealing compound.

Table 9 Types of protection for gas explosion protection

3.2.2 Special types of protection for Zone 2

The type of protection "n" for Zone 2 includes several different types, of which several represent simplifications of the types of protection listed above.

Type of protection	Symbol	Description
Non-sparking equipment	nA	Equipment does not generate sparks during normal operation (switch, relay etc.)
Protected sparking equipment	nC	Sparking or hot parts are enclosed or in hermetically sealed housings
Gas-proof housing	nR	The housing is designed such that an explosive atmosphere can only penetrate to a very limited extent
Simplified pressurized enclosure	nP / nZ*)	Similar to pressurized enclosure with certain simplifications
Energy-limited equipment	nL	Intrinsic safety during non-faulty operation, no consideration of safety-relevant faults

*) According to EN 50021 / IEC 60079-15

Table 10 Special types of protection for Zone 2

3.3 Equipment groups, explosion groups

3.3.1 Equipment groups

Equipment for explosive atmospheres is divided into two groups:

Group	Explanation
Equipment group I	Equipment for use • in underground plants • in mines • and their surface plants
Equipment group II	Equipment for use in other areas

Table 11 Equipment groups for explosive atmospheres

3.3.2 Explosion groups

The electrical equipment of group II is divided further into explosion groups. This division depends on the maximum experimental safe gap and the minimum ignition current ratio:

Explosion group	Maximum experimental safe gap	Minimum ignition current ratio	Danger	Equipment requirements
II A	> 0.9 mm	> 0.8	Low	Low
II B	0.5 mm to 0.9 mm	0.45 to 0.8	Medium	Medium
II C	< 0.5 mm	< 0.45	High	High

Table 12 Explosion groups of equipment group II

The maximum experimental safe gap (MESG) and the minimum ignition current (MIC) are determined for various gases and vapors under exactly defined experimental conditions.

- **Maximum experimental safe gap:** This is the gap at which a flame flashover just no longer takes place in a test vessel with a gap length of 25 mm.
- **Minimum ignition current**: The spark must have a minimum energy content in order to ignite an explosive atmosphere. The minimum energy content required is a specific property of the explosive gas or vapor. A measure of this is the minimum ignition current ratio: this is the ratio between the minimum ignition current of the respective gas and the minimum ignition current of the laboratory value for methane.

3.4 Temperature classes

The ignition temperature of a flammable gas/liquid is the lowest temperature of a hot surface at which ignition of the gas/air or vapor/air mixture takes place. The maximum surface temperature of the equipment must therefore be lower than the ignition temperature of the ambient atmosphere.

The temperature classes T1 to T6 have been introduced for electrical equipment of explosion group II. The equipment is assigned to a temperature class according to its maximum surface temperature. Equipment corresponding to a higher temperature class may also be used for applications requiring a lower temperature class.

Temperature classes according to IEC/CENELEC/ NEC 505	Temperature classes according to NEC 500	Max. permissible surface temperature of equipment in °C	Ignition temperatures of flammable substances in °C
T1	T1	450	> 450
T2	T2	300	> 300 to 450
	T2A	280	> 280 to 300
	T2B	260	> 260 to 280
	T2C	230	> 230 to 260
	T2D	215	> 215 to 230
T3	T3	200	> 200 to 300
	T3A	180	> 180 to 200
	T3B	165	> 165 to 180
	T3C	160	> 160 to 165
T4	T4	135	> 135 to 200
	T4A	120	> 120 to 135
T5	T5	100	> 100 to 135
T6	T6	85	> 85 to 100

Table 13 Temperature classes of explosion group II

3.5 Explosion protection for non-electrical equipment

The ATEX guideline 94/9/EC refers generally to "Equipment and protective systems for normal operation in hazardous areas". This includes electrical as well as non-electrical equipment. Many involved parties, manufacturers and users actually became really aware of this fact very late. One of the results is that practically no harmonized standards are available yet for non-electrical equipment. The range of standards EN 13463-x "Non-electrical equipment for use in hazardous areas" (see Section 2.2.2) are still mainly in the draft stage, and cannot therefore be applied as a basis for development and approval (with exception of EN 13463-1).

Typical non-electrical equipment which may present a potential danger include motors, gear units, pumps, light metal parts, units which include sources of heat or which could overheat etc.

The procedure among the named parties and agreed upon with the manufacturers currently envisages that a detailed risk analysis according to the EN 13463-1 standard is carried out by the manufacturer for all non-electrical equipment defined for use in Zone 1 or 2. The corresponding documents will be deposited there in agreement with a named party. The products may be marketed with a conformity declaration if they have been assessed as being sufficiently safe according to the result of the risk analysis. However, a prototype test similar to that for electrical equipment is essential for products defined for use in Zone 0. The associated testing agency (named party) then also issues an EC Type Examination Certificate for it.

4 Identification of explosion-proof equipment

4.1 Identification in zones according to the zone model

4.1.1 Overview

The division according to zones is used in Europe (CENELEC), in North America (NEC 505) and in the IEC.

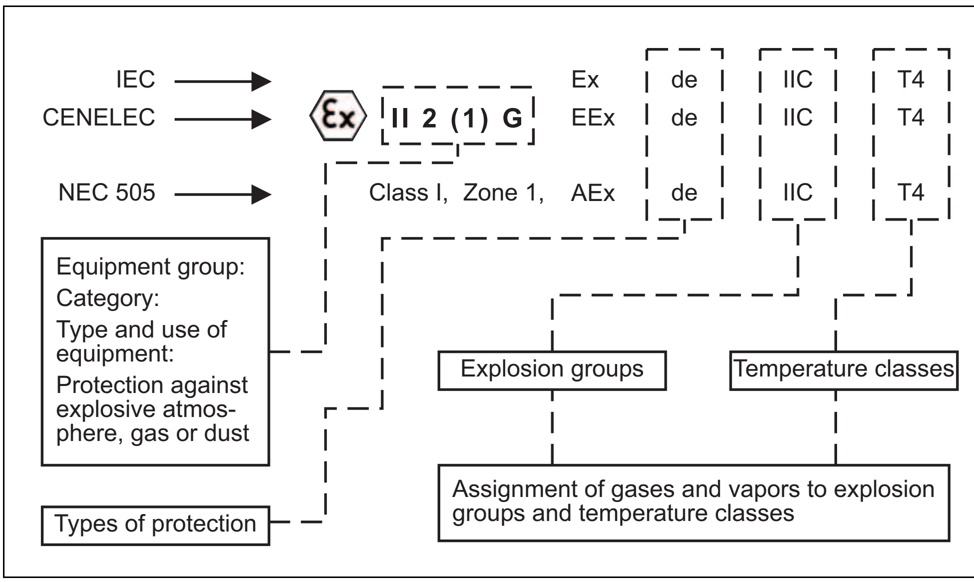


Fig. 4 Identification according to IEC / CENELEC / NEC 505

4.1.2 Equipment group I

Equipment group I		
Category	M1	M2
Requirement	Very high degree of safety	High degree of safety
Sufficient safety	Independent faults can be handled. Two independent equipment protection measures required	The equipment must be switched off when a potentially explosive atmosphere occurs

Table 14 Equipment group I for equipment in underground plants of mines and their surface plants which can be endangered by mine gas or flammable dusts

4.1.3 Equipment group II

Equipment group II						
Category	1		2		3	
Requirement	Very high degree of safety		High degree of safety		Normal degree of safety	
Sufficient safety	On occurrence of two independent faults in normal operation and with seldom equipment faults. Two independent equipment protection measures required		For normal operation and frequently occurring equipment faults as well as with fault states to be commonly expected		With normal (fault-free) operation	
Use in	Zone 0	Zone 20	Zone 1	Zone 21	Zone 2	Zone 22
Atmosphere G = gas, D = dust	G	D	G	D	G	D

Table 15 Equipment group II for equipment in other hazardous areas

4.1.4 Types of protection, explosion groups and temperature classes

Type of protection	**Symbol**	**Explosion group**		**Temperature class**	
		Explosion group	**Typical gas**	**Max. permissible surface temperature**	**CENELEC/ IEC USA (NEC 505)**
Increased safety	e	I	Methane	450 °C	T 1
Flameproof enclosure	d	II A	Propane	300 °C	T 2
Pressurized enclosure	p	II B	Ethylene	200 °C	T 3
Intrinsic safety	i*)	II C	Hydrogen	135 °C	T 4
Oil immersion	o			100 °C	T 5
Sand filling	q			85 °C	T 6
Encapsulation	m				
Type of protection	n				

*)
ia= use in Zone 0, 1, 2;
ib= use in Zone 1, 2;
[EEX ia]= associated electrical equipment. Installation in non-hazardous area. Cables of the intrinsically-safe connections may lead into Zone 0, 1 or 2.

Table 16 Types of protection, explosion groups and temperature classes

4.1.5 Classification of gases and vapors in explosion groups and temperature classes

	T 1	T 2	T 3	T 4	T 5*)	T 6
I	Methane					
II A	Acetone Ethane Ethyl acetate Ammonia Benzene (pure) Acetic acid Carbon monoxide Methane Methanol Propane Toluene	Ethyl alcohol i-amyl acetate n-butane n-butyl alcohol	Gasoline Diesel fuel Jet fuel Fuel oils n-hexane	Acetaldehyde Ethyl ether		
II B	City gas (coal gas)	Ethylene				
II C	Hydrogen	Acetylene				Carbon bisulfide

*) No gas is currently known which corresponds to temperature class T5. Thus the specification of temperature class T5 for equipment has no significance and is usually only specified for advertising purposes.

Table 17 Classification of gases and vapors in explosion groups and temperature classes

4.2 Identification according to the North American Class/ Division model

4.2.1 Overview

The identification according to Divisions is used in the USA and Canada.

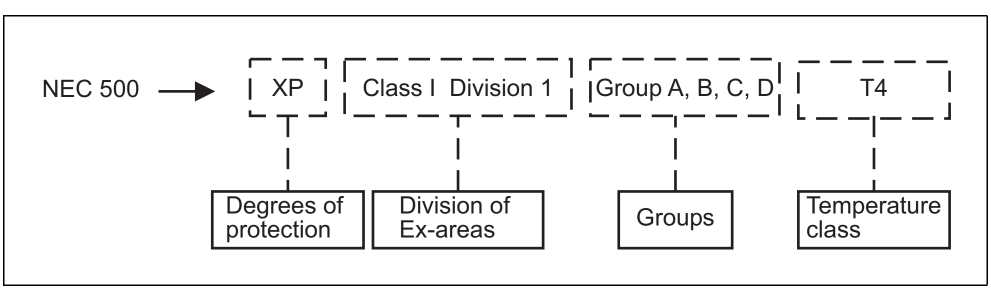


Fig. 5 NEC 500 overview

4.2.2 Degrees of protection

Type of protection	Meaning
XP	**Explosion-proof:** comparable with flameproof enclosure. Stipulated for Group A-D in Division 1 or 2.
IS	**Intrinsically-safe:** comparable with intrinsic safety. Stipulated for Group A-D in Division 1 or 2.
X, Y or Z	**Pressurized:** comparable with pressurized enclosure • X, Y used for Division 1 • Z used for Division 2
DIP	**Dust-ignition-proof:** degree of protection refers to dust explosion. Stipulated for Group E-G in Division 1 or 2.
NI	**Non incendive:** comparable with degree of protection n. Used in Division 2.

Table 18 Degrees of protection

4.2.3 Division of Ex areas NEC 500

Division		Division 1	Division 2
Assignment of substance	Gas/vapors	Class I	Class I
	Dusts	Class II	Class II
	Fibers/fluff	Class III	Class III

Table 19 Division of Ex areas NEC 500

4.2.4 Temperature classes

Max. permissible surface temperature	NEC 500
450 °C	T1
300 °C	T2
280 °C	T2A
260 °C	T2B
230 °C	T2C
215 °C	T2D
200 °C	T3
180 °C	T3A
165 °C	T3B
160 °C	T3C
135 °C	T4
120 °C	T4A
100 °C	T5
85 °C	T6

Table 20 Temperature classes

4.2.5 Classes and groups according to NEC 500

Typical gases, dusts, fluff and fibers	Group	
Acetylene	Class I	Group A
Hydrogen	Class I	Group B
Ethylene	Class I	Group C
Propane	Class I	Group D
Methane	Mining	
Metallic powder	Class II	Group E
Coal dust	Class II	Group F
... all other dusts (grain dust)	Class II	Group G
Fibers/fluff	Class III	

Table 21 Classes and groups according to NEC 500

4.3 Examples of identifications for explosion-proof equipment

4.3.1 Example: explosion-proof equipment

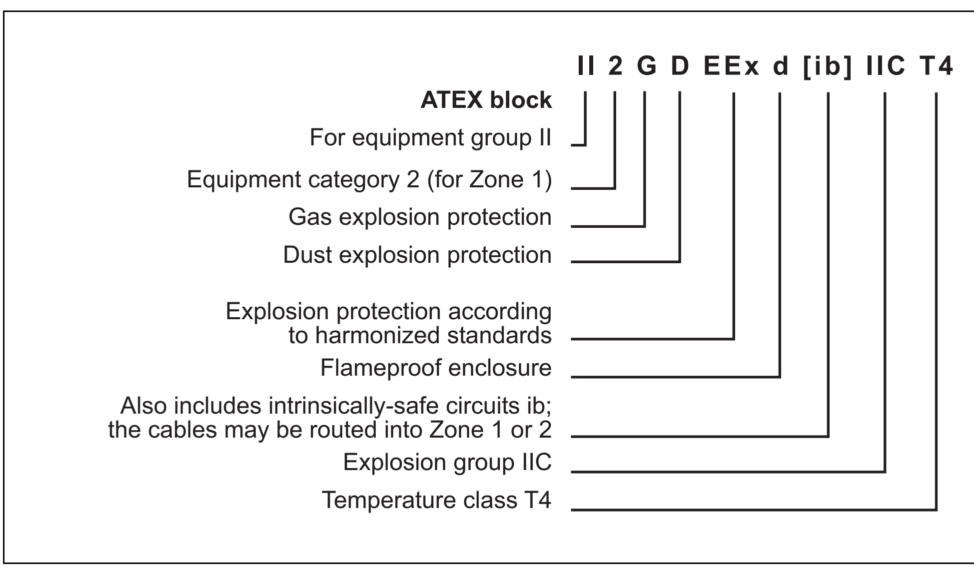
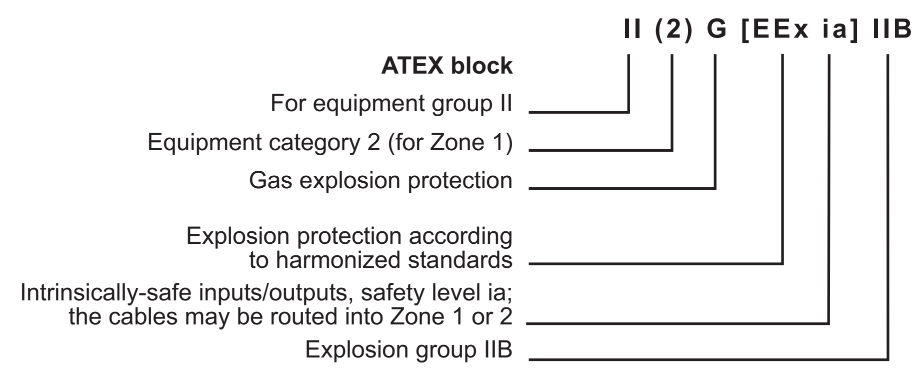


Fig. 6 Example: explosion-proof equipment

4.3.2 Example: associated equipment



The intrinsically-safe inputs/outputs of the associated equipment may be routed into the hazardous area. The equipment itself may only be installed outside the hazardous area.

Fig. 7 Example: associated equipment

4.3.3 Example: US identification according to NEC 500

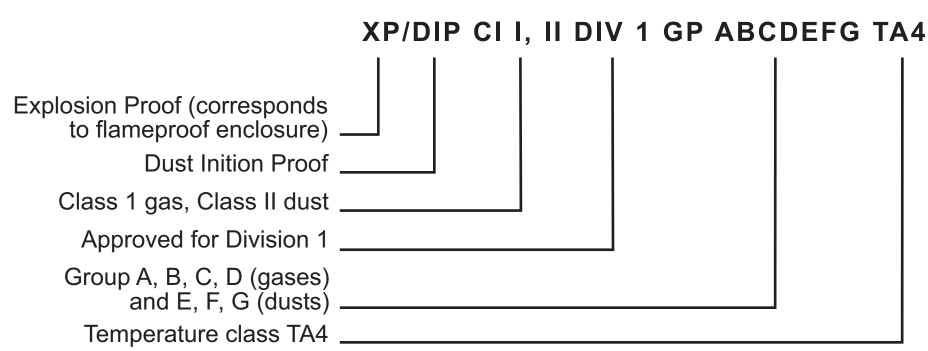


Fig. 8 Example: US identification according to NEC 500

4.3.4 Example: US identification according to NEC 505

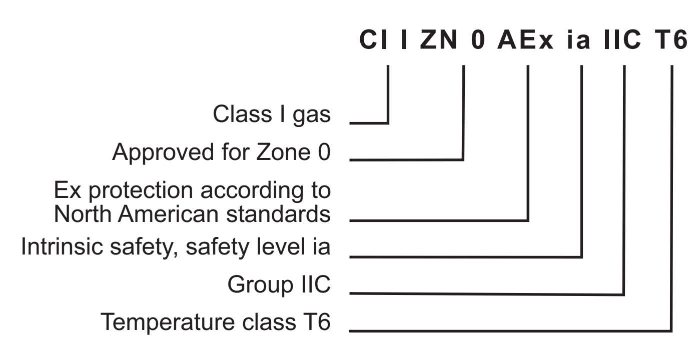


Fig. 9 Example: US identification according to NEC 505

4.4 Types of protection for enclosures

4.4.1 IP types of protection (ingress protection) according to EN 60529 (IEC 529)

The IP classification of the type of protection for enclosures is the most frequently used system worldwide. It corresponds to the European and international IEC standard.

The IP system differentiates between protection against foreign objects (digit 1) and protection against water (digit 2).

Protection against foreign objects	IP		Protection against water
	Digit 1	Digit 2	
No protection	0	0	No protection
Foreign objects > 50 mm	1	1	Vertically falling drip water
Foreign objects > 12 mm	2	2	Drip water falling at an angle
Foreign objects > 2.5 mm	3	3	Spray water
Foreign objects > 1 mm	4	4	Water from hose
Dust protection	5	5	Water jet
Dustproof	6	6	Strong water jet
		7	Occasional submersion
		8	Staedily submersion

Table 22 IP degrees of protection according to EN 60529 (IEC 529)

4.4.2 Types of protection for enclosures according to ANSI / NEMA 250 (USA)

The American classification system for enclosure protection according to NEMA is significantly different from the IP system used in Europe and also by the IEC. The standard differentiates three application classes:

- Enclosure for indoor non-hazardous locations
- Enclosure for outdoor non-hazardous locations
- Enclosure for hazardous locations

The types of protection for enclosures in explosive atmospheres (hazardous locations - types 7, 8, 9, 10) are based on those for non-hazardous locations in that special explosion requirements (e.g. pressure test for explosion-proof enclosures) are additionally checked. It has largely become established in the USA in the meantime to only use the non-hazardous types since the explosion protection must be checked and certified by an authorized testing authority anyway (e.g. FM, UL, CSA).

The types of enclosure most commonly used nowadays also for explosion-proof field devices are therefore the outdoor enclosure types 4, 4X, 6 and 6P with appropriate application in conjunction with explosion-proof certification.

Provides a degree of protection against the following environmental conditions	**Type of enclosure**						
	3	**3R**	**3S**	**4**	**4X**	**6**	**6P**
Incidential contact with enclosed equipment	X	X	X	X	X	X	X
Rain, snow, sleet	X	X	X	X	X	X	X
Sleet - ice covered			X				
Windblown dust	X		X	X	X	X	X
Hosedown				X	X	X	X
Corrosive agents (salt water)					X		X
Occasional temporary submersion						X	X
Occasional prolonged submersion							X

Table 23 Specific requirements for enclosures for outdoor non-hazardous locations according to NEMA 250

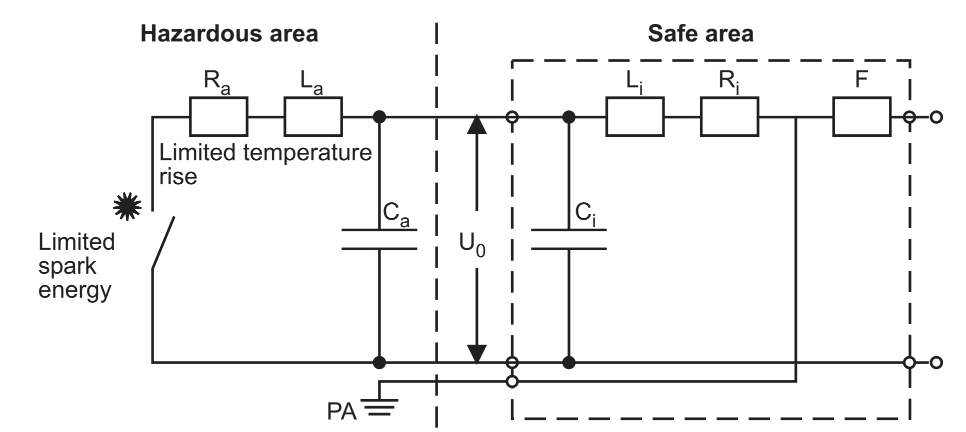
5 Intrinsic safety and intrinsically-safe circuit

5.1 Principles

The physical principle for the type of protection "Intrinsic safety" is that a certain minimum ignition energy is required to ignite an explosive atmosphere. In an intrinsically-safe circuit, this minimum ignition energy is not present in the hazardous area, neither during normal operation nor in the event of a fault. The intrinsic safety of a circuit is achieved by limiting the current, voltage, power and temperature. Therefore the type of protection "Intrinsic safety" is limited to circuits with relatively small powers.

To prevent sparks during closing or opening, the capacitance and inductance of an intrinsically-safe circuit are also limited depending on the maximum current and voltage values. No sparks or thermal effects which could lead to ignition of an explosive atmosphere occur either in normal operation or in the event of a fault. Therefore intrinsically-safe circuits may also be connected or disconnected during operation when live since the safety is also guaranteed in the event of a short-circuit or interruption.

The following figure shows the block diagram of the type of protection "Intrinsic safety":



U_0 = Max. output voltage
I_0 = Max. output current
R_i = Internal resistance
L_i = Internal inductance
C_i = Internal capacitance
F = Fuse
D = Z-diode
PA = Equipotential bonding
R_a = External resistance
L_a = External inductance
C_a = External capacitance

Fig. 10 Block diagram for voltage/current limiting with type of protection "Intrinsic safety"

Intrinsically-safe electrical equipment and intrinsically-safe components of associated equipment are divided into categories ("Protection level"). A differentiation is made between the protection levels "ia" and "ib", where protection level "ib" also provides protection should one protective measure fail (fault redundancy 1) and protective level "ia" also provides protection should two protective measures fail (fault redundancy 2). The standard refers to so-called "countable faults" instead of protective measures. These refer to protective measures such as current limiting resistors, Zener diodes for voltage limiting, fuses, safe distances etc., i.e. all components or measures which handle an exactly defined safety function for the associated equipment.

Protection level	Description according to EN 50020	Installation
ia	The intrinsically-safe electrical equipment must not cause an ignition • During normal operation or with the existence of those non-countable faults which result in the most unfavorable condition. • During normal operation or with the existence of a countable fault plus those non-countable faults which result in the most unfavorable condition. • During normal operation or with the existence of two countable faults plus those non-countable faults which result in the most unfavorable condition.	Up to Zone 0
ib	The intrinsically-safe electrical equipment must not cause an ignition • During normal operation or with the existence of those non-countable faults which result in the most unfavorable condition. • During normal operation or with the existence of a countable fault plus those non-countable faults which result in the most unfavorable condition.	Zone 2 Zone 1

Table 24 Protection levels of electrical equipment and intrinsically-safe components

5.2 Minimum ignition curves

The so-called minimum ignition curves are used to assess an intrinsically-safe circuit and to determine the maximum capacitance and inductance values. They are included in the valid intrinsically-safe standards (EN 50020 or DIN EN 50020, and IEC 60079-11 or EN 60079-11). Minimum ignition curves exist for the resistive, capacitive and inductive circuits. Different minimum ignition curves are applied depending on the gas group for which an intrinsically-safe circuit is to be designed, and take into account the minimum ignition energies of the gas groups.

5.3 Associated electrical equipment

Associated electrical equipment is a reference to equipment which contains one or more intrinsically-safe circuits but in which not all circuits are intrinsically-safe Associated electrical equipment usually has an isolating function, i.e. separating intrinsically-safe equipment from non-intrinsically-safe equipment within a signal circuit. Such devices include e.g.: safety barriers, isolating switching amplifiers, power supply units etc.

Associated electrical equipment is not explosion-proof and must therefore not be installed in the hazardous area. It only contains intrinsically-safe circuits which may be routed into the hazardous area.

Associated electrical equipment is identified by a square bracket enclosing the "EEx" and the symbol for the type of protection, as well as absence of the temperature class, e.g. [EEx ib] IIC.

5.4 Cables

DIN / EN 60 079-14 (VDE 165, Part 1) must be observed when selecting and routing the cables. Particular attention must be paid to the characteristic values such as electric strength and minimum cross-section. In the case of intrinsically-safe circuits, the cable capacitance and inductance must be observed in addition, and must not exceed the values specified for the intrinsically-safe or associated equipment used (Co, Lo). The connection points and cables of intrinsically-safe circuits must be identified, e.g. in light blue, and be separated from the other connection points and cables of non-intrinsically-safe circuits.

5.5 Isolating stages and safety barriers

The basic design of an intrinsically-safe system for measurement and control in hazardous areas is shown in Fig. 6-7. The associated automation and display equipment (which need not be explosion-proof) is located outside the hazardous area, e.g. in a control room. However, all field circuits leading into the hazardous area must be designed as intrinsically-safe. Isolating stages between the intrinsically-safe field circuits and the non-intrinsically-safe control room circuits provide the voltage and current limiting required for the intrinsically-safe area.

The isolating stages for actuators and sensors can also be designed as separate equipment, e.g. as isolating transformers or safety barriers, or integrated into the programmable controllers as is e.g. the case with the SIMATIC Ex modules. There are versions with and without electrical isolation.

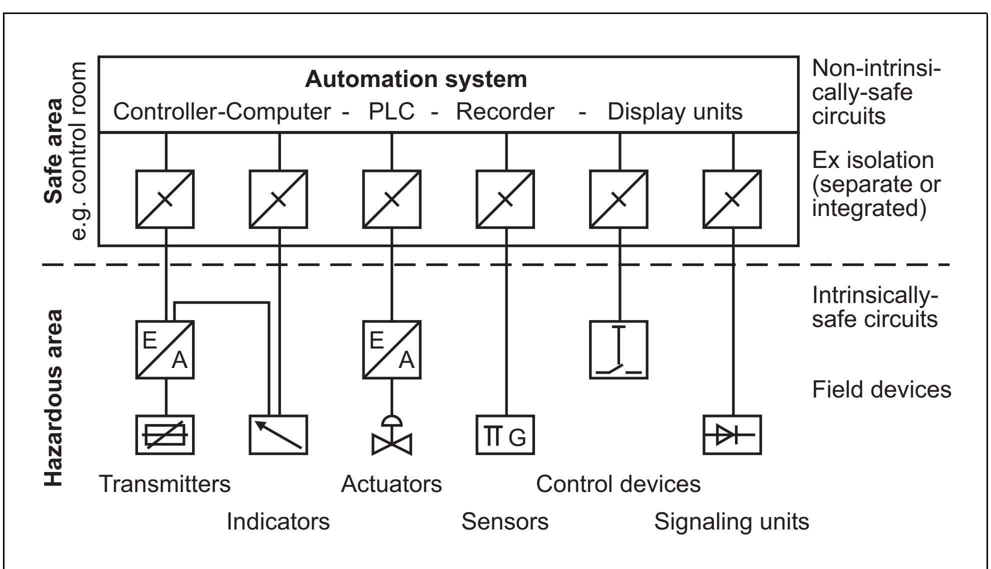


Fig. 11 Typical design of an intrinsically-safe measurement and control system

5.6 Connections in the intrinsically-safe circuit

The connection of intrinsically-safe or associated equipment results in a new circuit whose electrical properties have to be checked for compatibility with the rules associated with intrinsic safety. A differentiation is made between three types of circuit:

Connection of

- Two intrinsically-safe devices
- One intrinsically-safe device and associated equipment
- More than one associated or active equipment

Testing of the acceptability of the connection is generally relatively easy in the first two cases, and is carried out by comparing the safety parameters from the EC-type examination certificate or the technical data of the manufacturer. Case three can be more complicated, and should only be carried out by persons with the required knowledge.

5.6.1 Connection of two intrinsically-safe devices or one intrinsically-safe and one associated equipment

The connection rules are defined in the installation regulations of the EN 60079-14 or IEC 60079-14 standard. In accordance with this, the safety-oriented maximum values of the input/output parameters must be compared to check whether the connection of two devices with intrinsically-safe circuits satisfies the requirements for intrinsic safety.

The following conditions must be fulfilled:

Maximum values of feed output		**Maximum values of (passive) input**
U_o	≤	U_i
I_o	≤	I_i
P_o	≤	P_i
L_o	≥	$L_i + L_{cable}$
C_o	≥	$C_i + C_{cable}$
L_o / R_o	≥	L_{cable} / R_{cable} (L_i =! 0)

Table 25 Connection rules for two intrinsically-safe devices or one intrinsically-safe and one associated equipment

The connection is only permissible if all required conditions are satisfied. Not all parameters listed above are specified for some devices, e.g. if only two of the three parameters U, I, P are satisfied for a resistive output or input, the system is unambiguously defined. The L/R ratio is not essential either. However, if the L/R ratio is specified, and if the internal inductance of the intrinsically-safe equipment is Li = 0, the condition for Lo need not be fulfilled.

5.6.2 Connection with more than one associated or active equipment

These cases require a detailed safety analysis. The procedure also depends on the shape of the device characteristic. A procedure for safety analysis is specified in

Appendix A and B of the installation standard EN /IEC 60079-14 or VDE 0165 T.1 for linear current/voltage characteristics.

For the more complicated case of non-linear characteristics, the Physikalisch Technische Bundesanstalt describes in report PTB-ThEx-10 a procedure with which the intrinsic safety of such connections can be proven in a graphical manner. However, these considerations should always be carried out by experts.

A system description must be produced by the planner in which the individual electrical equipment and the electrical characteristic values of the system including the connection cables are defined. The IEC 60079-25 standard for intrinsically-safe systems describes the calculation and analyses procedures as well as a procedure for documentation of an intrinsically-safe system.

5.6.3 Example of the connection of two intrinsically-safe devices

Proof of the intrinsic safety for the connection of a SITRANS P DSIII pressure transmitter to an analog input module of the SIMATIC ET 200iS distributed I/O station.

Devices:

Module 2AI 2WIRE analog input	**Type 6ES7 134-5RB00-0AB0**
EC-type examination certificate	KEMA 01 ATEX 1152 X
Degree of protection	II 2(1)G EEx ib[ia] IIC T4
Intrinsically-safe pressure transmitter SITRANS P DSIII	**Type 7MF4*33-*****-*B****
EC-type examination certificate	PTB 99 ATEX 2122
Degree of protection	II 1/2 G EEx ia IIC/IIB T6

Table 26 Example of the connection of two intrinsically-safe devices

Connection:

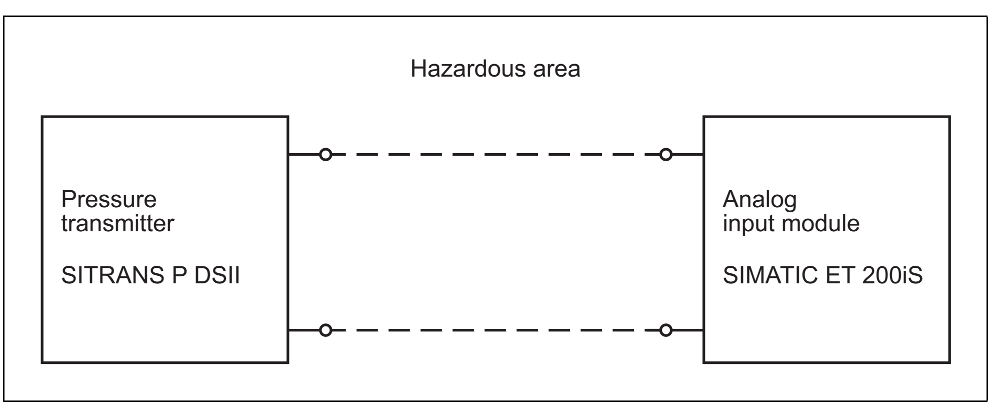


Fig. 12 Connection of a pressure transmitter to an analog input module

Since both devices are explosion-proof, they can both be installed in the hazardous area of Zone 1.

Comparison of safety-relevant maximum values:

SIMATIC analog input module 6ES7 134-5RB00-0AB0			**SITRANS P DSIII Type 7MF4*33-*****-*B****		
U_0	28 V	≤	U_i	30 V	OK
I_0	85 mA	≤	I_i	100 mA	OK
P_0	595 mW	≤	P_i	750 mW	OK

Table 27 Comparison of safety-relevant maximum values

Result of comparison: the connection of these devices is permissible.

Calculation of the maximum cable length:

	L_0 [mH]		**L_i [mH] (cell)**		**L [mH] (cable)**	**Maximum permissible cable length with L'=1 uH/m**
Gr. II B	15	-	0.4	=	14.6	14600 m
Gr. II C	4	-	0.4	=	3.6	3600 m

Table 28 Calculation of the maximum cable length on the basis of the inductance

	C_0 [nF]		**C_i [nF] (cell)**		**C [nF] (cable)**	**Maximum permissible cable length with C'= 200 pF/m**	**Maximum permissible cable length with C'= 100 pF/m**
Gr. II B	650	-	6	=	644	3220 m	6440 m
Gr. II C	80	-	6	=	74	370 m	740 m

Table 29 Calculation of the maximum cable length on the basis of the capacitance

The max. permissible cable length is 3220 m for gas group II B and 370 m for gas group II C (note - depends on type of cable used). One can recognize that the cable length is limited in this example by the capacitances of the circuit. The inductances would permit longer cables in each case.

Note

National feature for Germany according to DIN EN 60079-14 (national foreword):

This type of calculation is only recommended if the connected equipment only contains lumped inductances or capacitances. This type of calculation is permissible for mixed circuits if the values for Lo and Co specified for the feeding equipment represent pairs of values for mixed circuits. This must be specifically indicated in the type examination certificate. This must be particularly observed for Zone 0 applications.

5.6.4 Example of the connection of intrinsically-safe equipment with associated equipment.

Proof of intrinsic safety for connection of a SIWAREX R load cell with a SIWAREX IS Ex-i interface.

Devices:

SIWAREX R load cell	**Type 7MH5 101-... RN-...., rated load 10 t**
EC-type examination certificate	KEMA 00 ATEX 1133 X
Degree of protection	II 2 G EEx ib IIC T6
Ex-i interface SIWAREX IS	**Type 7MH4710-5CA**
EC-type examination certificate	TÜV 01 ATEX 1722 X
Degree of protection	II (2) G [EEx ib] IIC

Table 30 Example of the connection of intrinsically-safe equipment with associated equipment

Connection:

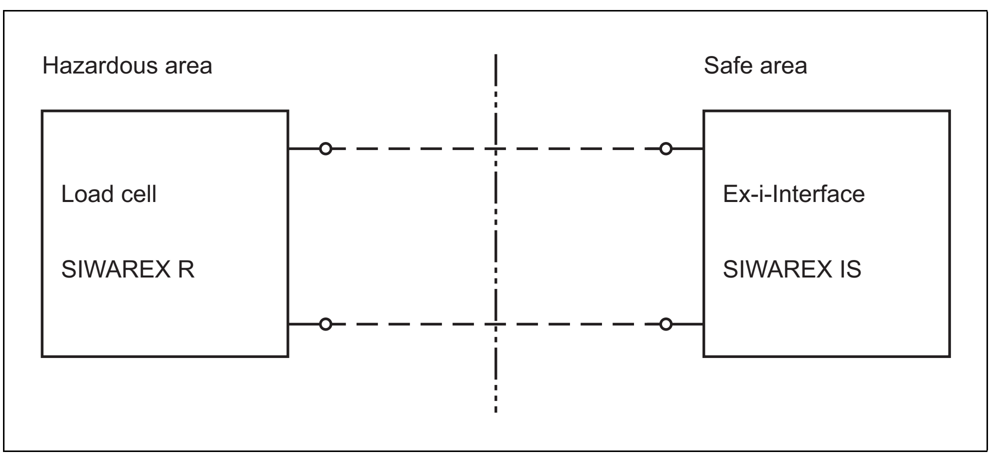


Fig. 13 Connection of a SIWAREX R load cell with a SIWAREX IS Ex-i interface

The interface is associated electrical equipment and must only be installed outside the hazardous area.

Comparison of safety-relevant maximum values:

Ex-i interface 7MH4710-5CA			Load cell Rated load 10 t		
U_0	14.4 V	≤	U_i	19.1 V	OK
I_0	137 mA	≤	I_i	323 mA	OK
P_0	1025 mW	≤	P_i	1.25 W for T6	OK
P_0	1025 mW	≤	P_i	1.93 W for T4	OK

Table 31 Comparison of safety-relevant maximum values

Result of comparison: the connection of these devices is permissible for the temperature ranges T4 and T6.

Calculation of the maximum cable length:

	L_0 [mH]		L_i [mH] (cell)		L [mH] (cable)	Max. perm. Cable length with L'=1 uH/m
Gas gr. B	2	-	0	=	2	2000 m
Gas gr. C	0.5	-	0	=	0.5	500 m

Table 32 Calculation of the maximum cable length on the basis of the inductance

	C_0 [nF]		C_i [nF] (cell)		C [nF] (cable)	Max. perm. cable length with C'= 200 pF/m	Max. perm. cable length with C'= 100 pF/m
Gas gr. B	2000	-	0.4	=	1999	9 995 m	19 990 m
Gas gr. C	450	-	0.4	=	449	2 245 m	4 490 m

Table 33 Calculation of the maximum cable length on the basis of the capacitance

The max. permissible cable length is 2000 m for gas group II B and 500 m for gas group II C. In this example, the cable length is limited by the inductances of the circuit. The capacitances would permit longer cables for both types with 100 and 200 pF/m.

6 Installation, operation and maintenance of electrical systems in hazardous areas

6.1 Installation in Zone 1

Areas corresponding to Zone 1 are often defined in the vicinity of filling and emptying openings. Electrical equipment for Zone 1 (device category 2) - except cables and conductors - must comply with the requirements of the individual types of protection and be certified by an approved test authority. This does not apply to so-called simple equipment where none of the values 1.5 V, 0.1 A or 25 mW (EN 50020) is exceeded according to the manufacturer's data. These require neither a certificate nor a symbol.

6.1.1 Equipotential bonding

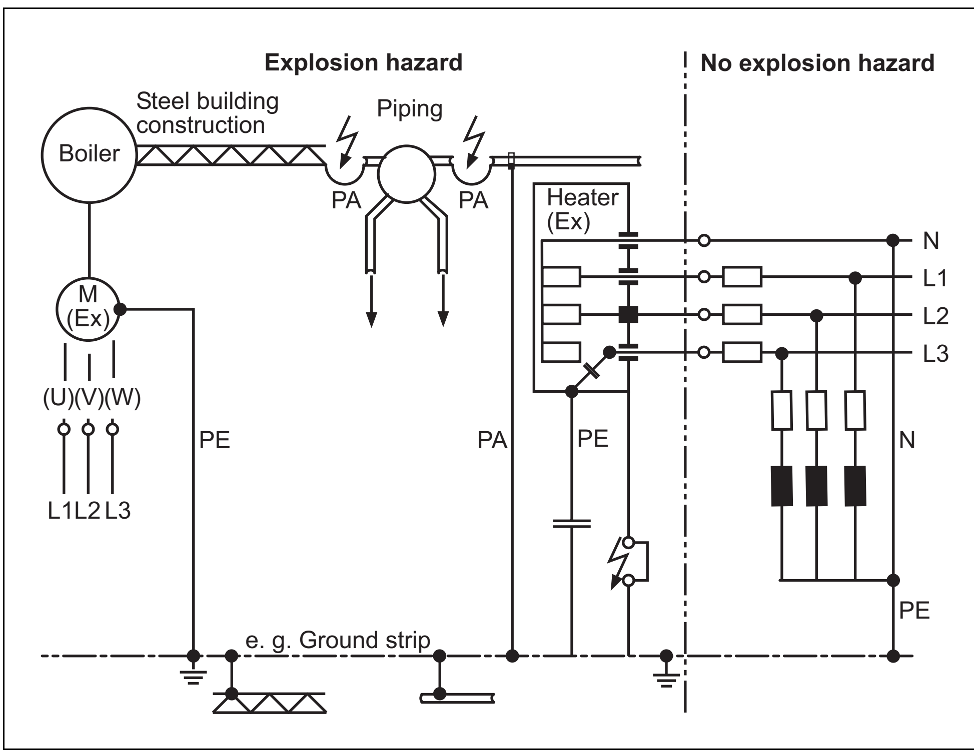


Fig. 14 Equipotential bonding in a hazardous area

The EN 60079-14 installation directive requires equipotential bonding within hazardous areas of Zones 0 and 1 to prevent the occurrence of sparks capable of causing ignition or of a temperature rise caused by potential differences. Implementation of the equipotential bonding must comply with the system configuration to DIN VDE 0100 Part 410 and the design ratings to DIN VDE 0100 Part 540. See IEC 60364-4-41 for additional information. Full equipotential bonding is achieved by connecting not only the housings of the electrical equipment into the equipotential bonding, but also all other accessible, conductive structural parts such as building construction, metal containers, piping etc. Extraneous conductive parts which do not belong to the structure or installation of the system (e.g. door frames, window frames) need not be incorporated into the equipotential bonding. This also applies to housings if their method of fixing provides reliable contact with structural parts for piping already involved in equipotential bonding. The connections for equipotential bonding must be reliable, e.g. using secured screw terminals.

6.1.2 Cables and conductors

When selecting cables and conductors, only use those which can withstand the expected mechanical, chemical and thermal influences. Cables and conductors with thermoplastic sheath, duroplastic sheath, elastomer sheath or mineral insulation with metal sheath may be used for fixed routing. Cable branch lines must comply with the requirements for hazardous areas.

The cables and conductors must be connected to the electrical equipment in line with the directives for the associated type of protection. Unused openings on devices and equipment must be closed. When cables and conductors are installed through openings into non-hazardous areas, care must be taken to provide an adequate seal at the openings (e.g. sand filling, mortar) to prevent carrying-over of the zone. At particularly hazardous points, cables and conductors must be protected against thermal, mechanical or chemical stress by, for example, conduits, tubing or covers. The flame retardance of cables and conductors for fixed routing must be proven in accordance with IEC 60332-1.

6.1.3 Intrinsically-safe equipment in Zone 1

Selection of equipment

A requirement for selecting equipment for systems with intrinsically-safe circuits is that only intrinsically-safe equipment of category 1G or 2G with protection level "ia" or "ib" according to EN 50020 may be used.

Simple electrical equipment (e.g. switches, resistors) need not be marked, but they must comply with the requirements of EN 50020 or EN 60079-11 and EN 50014 or EN 60079-0 wherever the intrinsic safety depends on it.

Note:

Associated electrical equipment with type of protection "Intrinsic safety" must be positioned outside the hazardous area. However, its inputs or outputs may be routed into the hazardous area.

Requirements of cables and conductors

Cables and conductors in intrinsically-safe circuits must always be insulated and withstand a test voltage of at least 500 V AC between conductors and between a conductor and ground. The diameter of a single conductor within the hazardous area must not be less than 0.1 mm. Where certain requirements are met, such as those for conductor insulation, test voltage, shielding etc., it is permissible to route more than one intrinsically-safe circuit in a cable or cable duct.

Cables and conductors of intrinsically-safe circuits must be marked, e.g. by means of a light blue cable sheath. The connection components of the intrinsically-safe circuits must also be marked, e.g. in light blue.

Intrinsically-safe cables, conductors, terminals etc. can also be marked in a different manner. However, if a color marking is used, it must be light blue.

Requirements of intrinsically-safe circuit

Intrinsically-safe circuits can be floating or also grounded. If grounded or non-isolated circuits are used, correct equipotential bonding must be provided. Furthermore, in Zone 1, conductors of intrinsically-safe and non-intrinsically-safe circuits must not be routed together in cables, conduits or bundles. Conductors of intrinsically-safe and non-intrinsically-safe circuits must be routed separately in cable ducts, or they must be separated by an intermediate layer of insulating material. This additional separation can be omitted, for example, by using conductors with suitable jacket insulation.

The intrinsic safety must not be impaired by external electrical or magnetic fields. It is therefore advisable to use shielded and/or twisted lines.

Proof of intrinsic safety

Proof of the intrinsic safety of a circuit is that the electrical characteristic data on the type test certificate or in the operating instructions of the equipment are observed. Conductors can be represented as lumped capacitances and inductances. For intrinsically-safe circuits, it is sufficient to determine the maximum capacitance between two adjacent cores. With standard commercially-available cables and conductors, a capacitance of 200 nF/km can be taken as a rough basis. Where intrinsically-safe circuits are connected to more them one active equipment, the intrinsic safety must also be guaranteed during fault situations. This must be proven by calculation or measurement.

6.2 Installation in Zone 0

Installation in Zone 0 is covered by requirements in addition to those for Zone 1 (see EN 60079-14).

Areas corresponding to Zone 0 usually occur within containers and tanks, and in the immediate vicinity of filling centers. Only electrical equipment may be used in Zone 0 which has been specifically certified and approved for this.

Increased requirements also apply to cables/conductors and their routing.

For systems with intrinsically-safe circuits, the requirement also exists that the intrinsically-safe and associated electrical equipment must correspond to devices of category 1G with protection level ia.

6.3 Installation in Zone 2

Zone 2 includes e.g. areas in the vicinity of flange connections for piping, production and storage locations for flammable and explosive materials, and other areas where a danger of explosion only exists in exceptional cases, and not during normal operation.

Equipment of device category 3G can be used in Zone 2. Furthermore, the devices of categories 1G and 2G (always defined for use in Zones 0 and 1) can also be installed in Zone 2.

The same requirements generally apply to cables and conductors in Zone 2 as in Zone 1. At least degree of protection IP54 is required under operating conditions where no appropriate protection is provided against the penetration of foreign matter and liquids.

If energy-limited equipment is used, the maximum permissible external capacitances and inductances must be observed corresponding to the intrinsic safety in Zone 1. Cables can be considered here as lumped capacitances and inductances. Special conditions must be observed for certain types of protection with Zone 2, e.g. when using gas-proof housings or pressurized enclosures. The requirements of EN 60079-14 and VDE 0165, Part 1, also apply here.

6.4 Installation in Zones 20, 21, 22

Zones 20, 21, 22 are hazardous areas as a result of combustible dusts. If an explosion hazard additionally exists in these areas as a results of flammable gases, vapors and mists, the requirements for Zones 0, 1, 2 apply in addition.

Zone 20 includes areas which occur, for example, in grain silos. All equipment for Zone 20 must be specially approved for this use. The equipment must correspond to category 1D.

Zone 21 includes areas which occur, for example, in mills, coal depots etc. Combustible dust can also emerge from openings in the vicinity of filling centers, thus also representing a Zone 21 area. Combustible dust/air mixtures can also result from the production and deflagration of sulfur gas and the production of smolder spots. The equipment for Zone 21 must correspond to category 2D or 1D.

Zone 22 includes areas in which an explosive atmosphere can only be expected in the event of process faults, e.g. through swirled-up dust. There is no danger of explosion during normal operation. The equipment for Zone 22 must correspond to category 3D, 2D or 1D.

6.5 Operation, maintenance, faults and repairs

6.5.1 Operation and maintenance

According to the safe working conditions directive (BetrSichV), operation and maintenance of electrical systems in hazardous areas are the sole responsibility of the user. This means that the user must keep the system in a properly functioning state, operate it correctly, and supervise it continuously. Furthermore, the user must carry out maintenance and repairs as necessary without delay. The user is responsible for implementation of the required safety measures. Systems in hazardous areas are graded as requiring supervision according to the safe working conditions directive §1 Section 2 Clause 1 No. 3. A system requiring supervision may only be put into operation for the first time or following a significant modification if it has been checked for correctness by an approved supervision authority (see BetrSichV) taking into account the envisaged mode of operation. The inspection includes assembly, installation and safe functioning. In agreement with the approval authority, this inspection can also be carried out by a qualified person. It is clear that correct operation also includes observation of the generally recognized engineering rules, especially for electrical engineering. With respect to the proper operating state of the system, the safe working conditions directive requires inspection of a system at intervals of **max. 3 years**. The supervision authority can specify additional supervision measures in individual cases.

6.5.2 Faults

An explosion caused by operation of the electrical system must be reported by the user to the supervisory authority. This authority may require an examination of the cause of the explosion and the state of the system. Additional protective measures may then be necessary to rule out further faults.

6.5.3 Repairs

Repairs are only allowed if the specified protective measures for hazardous areas are observed. It is prohibited, for example, to work on live electrical equipment in hazardous areas. Working on intrinsically-safe circuits is an exception. Work may only be carried out by specially trained persons. Once the repairs have been completed, normal operation may only be resumed when the effectiveness of the required explosion protection measures has been proven. The supervisory authority or expert must issue a certificate to this effect, or apply a test symbol to the equipment.

7 Bus systems in hazardous areas

7.1 PROFIBUS PA intrinsically-safe fieldbus

PROFIBUS PA is the PROFIBUS version for process automation applications and has been specially optimized for the requirements of process engineering. Major features primarily include the interchangeability of devices from different vendors, the two-wire system, and the possibility for using in potentially explosive atmospheres. PROFIBUS-PA is standardized in DIN 19245, Part 4, and has also been adopted in the European fieldbus standard EN 50170. Furthermore, the physical layer complies with the international standard IEC 61158-2. The following table lists the most important properties.

	Physical layer according to IEC 1158-2, version H1
Baud rate	31.25 kbit/s
Topology	Linear or tree
Power supply	DC supply via bus cables
Explosion protection	Yes, intrinsically-safe design
Number of stations	Max. 32 (not Ex) Approx. 9 with gas group IIC (Ex) Approx. 23 with gas group IIB (Ex)
Max. cable length	1900 m
Max. branch length	120 m per spur line
Redundancy	Possible

Table 34 Properties of the PROFIBUS PA

7.1.1 Function

An important step for practical application of the PROFIBUS PA in potentially explosive atmospheres was the development of the FISCO model (Fieldbus Intrinsically Safe Concept) by the Physikalisch Technische Bundesanstalt, commissioned by various companies, including Siemens. According to this concept, each bus line may only be fed from one device, the segment coupler. All other stations on the bus (field devices, bus terminator) must be passive, and only absorb power. The average basic current absorbed is 10 mA. The signal amplitudes of the digitally modulated basic current are 19 and 1 mA.

In the meantime, the FISCO model has also become part of the explosion protection standards. It is internationally standardized as IEC 60079-27, and currently still has the status of a preliminary standard in Europe, but is to become a standardized appendix to an applicable intrinsically-safe standard (EN 50020 or EN 50039).

7.1.2 Rules for the design of an intrinsically-safe PROFIBUS PA segment in potentially explosive atmospheres

Important for users are the rules for configuring and installing a PROFIBUS PA system for applications in potentially explosive atmospheres, as well as the associated advantages when connecting the individual devices together. Particularly simple connection rules apply to PROFIBUS devices certified according to the IEC 60079-27 standard. The rating plate should be labelled "FISCO supply" for a bus feeder (segment coupler) or "FISCO device" for a bus station (e.g. field device). In such a case, the devices can be connected together without any further calculations as far as the explosion protection requirements are concerned. The cables used for the bus should be types which comply with the FISCO specification so that it is only necessary to observe the maximum permissible lengths. If other cables are used, special proof of the intrinsic safety must be provided with the defined cable parameters and lengths. No additional capacitors or inductors (apart from a certified bus terminator) may be connected into the bus circuit.

	EEx ia IIC	**EEx ib IIC/IIB**
Loop resistance	15 to 150 Ohm/km	15 to 150 Ohm/km
Inductance per unit length	0.4 to 1 mH/km	0.4 to 1 mH/km
Capacitance per unit length	80 to 200 nF/km	80 to 200 nF/km
Spur line length	30 m	30 m
Cable length	1 km	5 km

Table 35 Cable parameters according to FISCO specification

Intrinsically-safe FISCO devices must be designed according to the standard such that the requirements for gas groups IIC and IIB are satisfied. They can then be fed by any segment couplers. The certified type of the feeding coupler as a IIB or IIC device then defines the type of PROFIBUS segment, and thus also the permissible gas group of the application. The permissible number of devices on a bus line is calculated from the total current of all (passive) bus stations and the maximum current of the feeding device/segment coupler used, and can therefore have a different value for different applications.

7.1.3 Bus terminator

A PROFIBUS line must be provided with a bus terminator at each end in order to avoid signal reflections on the cable. A bus terminator is usually already integrated in the segment coupler so that a bus terminating element is only required at the other end of the line. Only an Ex-certified terminating element may be used for Ex applications. A bus terminator according to FISCO consists of an RC series connection with the following parameters:

- Resistance R: 90 to 100 Ohm
- Capacitance C: 0 to 2.2 uF

7.1.4 Shielding and earthing

The PROFIBUS-PA systems should usually be designed using shielded cables in order to guarantee interference-free operation according to the EMC requirements.

All cable shields must therefore be connected without interruption to the earthing connections of the devices and the (usually) metal housings. Housings of field devices and bus couplers may be connected to the local earth for functional and/or safety reasons. However, multiple earthing is only permissible in potentially explosive atmospheres if optimum equipotential bonding is provided between the hazardous and non-hazardous areas. If this cannot be guaranteed (e.g. with bus stations located far apart), the bus must only be earthed at one position to prevent dangerous compensating currents in earth loops. It is appropriate to only connect the cable shields to the local earth in the hazardous area (equipotential bonding) and to provide capacitive earthing in the non-hazardous area.

The isolating capacitor must satisfy the following requirements:

- Solid dielectric (e.g. ceramic)
- C = 10 nF
- Test voltage = 750 V AC / 1100 V DC

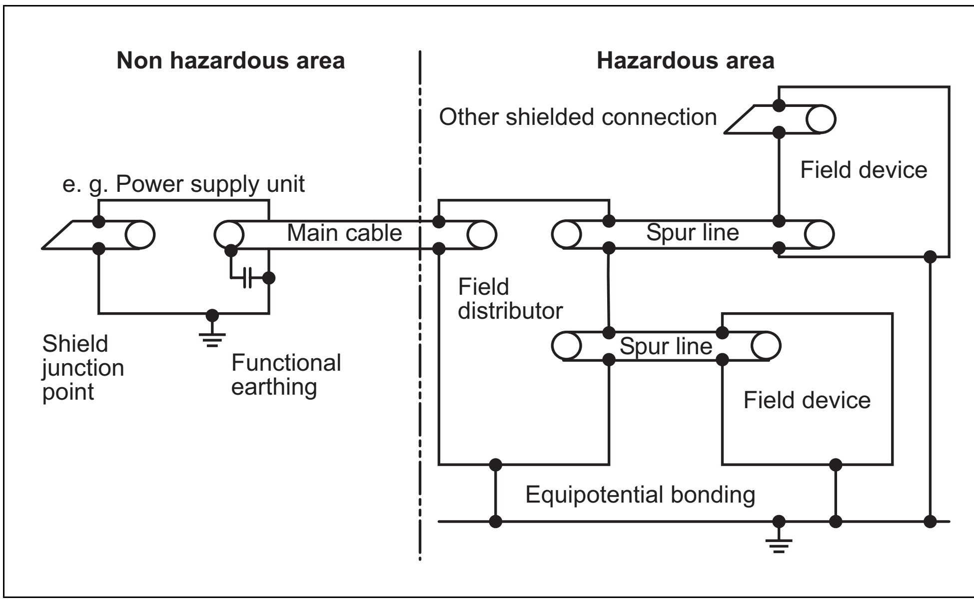


Fig. 15 PROFIBUS PA earthing

7.2 Fieldbus Foundation (FF bus)

The FF bus was developed in the USA as the counterpart to the European PROFIBUS. Whereas the PROFIBUS DP and PROFIBUS PA versions cover wide sectors of automation engineering, the FF bus specializes in the measuring and control sectors of applications in chemical and process engineering. The two bus systems have different protocols, and the function contents implemented are also different. Since the definition phase of the FF bus took much longer than originally planned, the number of field applications for PROFIBUS PA could achieve a significant lead.

For explosion-proof applications, the FF bus at the physical layer is also based on the FISCO model, i.e. the electrical interface for these devices is identical to that of the PROFIBUS PA devices. This results in a great simplification for approvals, since the same standards for explosion protection can be applied both in the USA and in Europe.

8 Appendix

8.1 Safety characteristics of flammable gases and vapors

The following table lists the ignition temperatures for various substances, and their assignment to the respective temperature classes and explosion groups.

Substance	Ignition temperature in °C	Temperature class	Explosion group
1,2-dichloroethane	440	T 2	II A
Acetaldehyde	140	T 4	II A
Acetic acid	485	T 1	II A
Acetic anhydride	330	T 2	II A
Acetone	540	T 1	II A
Acetylene	305	T 2	II C
Ammonia	630	T 1	II A
Benzene (pure)	555	T 1	II A
Carbon bisulfide	95	T 6	II C
Carbon monoxide	605	T 1	II A / II B
City gas (coal gas)	560	T 1	II B
Cyclohexanone	430	T 2	II A
Diesel fuels*)	220 to 300	T 3	II A
Ehylene	425	T 2	II A
Ethane	515	T 1	II A
Ethyl acetate	460	T 1	II A
Ethyl alcohol	425	T 2	II A / II B
Ethyl chloride	510	T 1	II A
Ethyl ether	170	T 4	II A
Ethyl glycol	235	T 3	II A
Ethylene oxide	440 (spontaneous decomposition)	T 1	II A
Fuel oil EL	220 to 300	T 3	II A
Fuel oil L*)	220 to 300	T 3	II A
Fuel oils M and S	220 to 300	T 3	II A
Gasoline (petrol) Initial boiling point < 135 °C	220 to 300	T 3	II A
Hydrogen	560	T 1	II C
Hydrogen sulfide	270	T 3	II B
i-amyl acetate	380	T 2	II A
Jet fuels	220 to 300	T 3	II A
Methane	595 (650)	T 1	II A

Table 36 Safety characteristics of flammable gases and vapors

Substance	**Ignition temperature in °C**	**Temperature class**	**Explosion group**
Methanol	455	T 1	II A
Methyl chloride	625	T 1	II A
Naphthalene	540	T 1	II A
n-butane	365	T 2	II A
n-butyl alcohol	340	T 2	II A
n-hexane	240	T 3	II A
n-propyl alcohol	405	T 2	-
Oleic acid	360 (spontaneous decomposition)	T 2	-
Petroleum spirit Initial boiling point > 135 °C	200 to 300	T 3	II A
Phenol	595	T 1	II A
Propane	470	T 1	II A
Tetraline (tetrahydronaphthalene)	425	T 2	-
Toluene	535	T 1	II A
*) These substances are not explosive at an ambient temperature up to 40 °C.			

Table 36 Safety characteristics of flammable gases and vapors

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