PROCESS AUTOMATION

MANUAL
EXPLOSION PROTECTION

Intrinsic Safety
Explosion Protection

PEPPERL+FUCHS
PROTECTING YOUR PROCESS

Notes on content:

This manual contains manuscripts of various presentations, each complete in and of itselves, that were given as part of a series of seminars by the three authors

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(Section 2, 3 and 5)

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(Section 9)

It is therefore possible that some text passages may be repeated. It does not appear necessary to assign numbers running from the beginning to the end of the manual to images, drawings and tables, etc. The list of references also refers only to the specific section in question.

It is not the goal of the authors to reproduce excerpts from standards in their entirety, but rather to give the general meaning. If further clarification is needed, the applicable standard should be consulted.

Notes on validity:

Attention

This document is based on national regulations and practices valid for Germany at the date of publishing. The respective valid national and regional standards and regulations must be observed. Subject to modification without notice.

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1 Statutory basis, EC directives on explosion protection

1.1 Introduction

In earlier times, explosions were closely associated with mining. Escaping minegas was ignited by a flame or spark, caused significant property damage as firedamp and usually took a toll in human life as well. Thus the mine disaster of 1913 in South Wales, which left 439 dead miners, could be seen as the event that inevitably gave birth to intrinsically safe ignition protection (see time line of explosion protection). Protection from explosions was therefore essential first and foremost in mining. As the industry emerged, there were initial reports of explosion caused by gas generated from coal that was used to heat steam boilers and thus to drive machines. As the widespread use of chemicals grew, especially petrochemicals, the number of explosions rose. Their effects became more and more devastating. By the end of the 19th century, Germany was issuing **Police Regulations** as they were known, according to which factory owners were required to take protective measures against explosions. Factory inspectors, as **labour inspectors** were then known, were responsible for monitoring observance of statutory regulations and ordering protective measures as warranted.

Over the course of time, much knowledge accumulated about how explosions came about and what caused them. Institutions such as the German Physical-Technical Reichs Institute (PTR, today PTB), the association of German Electrical Engineers (now VDE), the test gallery of the Mining Trade Union (BVS, now DMT) developed requirements (see 1903 and 1935 in the timeline), until the **Police Regulations on electrical equipment in hazardous areas and operating systems** were adopted on October 13, 1943. [1]

The first regulations on protection from explosions were classified as commercial law. The applicable law was the **Commercial Regulation**. The principle in this law is that the business owner is responsible for the protection of employees and third parties that could be affected. Thus the beginnings of environmental protection may be seen early on in this law. The Commercial Regulation was the legal basis for various **Technical Regulations**, which were in turn clarified by **Technical Rules**, which further refer to standards and VDE requirements. Special requirements were placed on individual potentially dangerous systems in these technical regulations. [2]

The Device Safety Law (GSG) in its version of August 26, 1992 also applies to setting up and operating systems that require monitoring, that serve business or commercial purposes and that could present hazards to those employed in them (§1a GSG). Electrical systems in especially hazardous areas are included among systems that require monitoring.

Simplification of the law did not occur in the Federal Republic of Germany until the **Industrial Safety Regulation** of September 27, 2002, since numerous individual regulations had gone out of force, including ElexV and VbF.

Time line of explosion protection

1744 The Royal Prussian field physician Dr. Ludolph causes a mixture of ethyl ether and air to ignite with an electrical spark

1883 "Regulation Governing the Commercial Sale and Partial Ownership of Petroleum"

1887 Approval of the Physical-Technical Reichs-Institute (PTR) in Berlin

1893 Founding of the Association of Electrical Engineers of Germany

1894 Renamed to VDE, the Association of German Electrical Engineers

1894 Founding of the Test Gallery of the Mining Trade Union (BVS) in Gelsenkirchen-Bismark

1895 First VDE Safety Requirements for high-voltage systems up to 250 V

1903 VDE 0100 "Requirements for Setting up Electrical Systems up to 1000 V" with the first mining requirements

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1906	Constitutive Session of the IEC in London (with participation of the VDE)
1912	VDE 0170 "Basic Principles for Designing Firedamp Devices on Electrical Machines, Transformers and Equipment" (1st version)
1913	439 miners lost their lives at a major mining explosion disaster in Sengheuydd (South Wales) on October 14, 1913 "due to sparks caused by an electrical signalling system or by falling rock" (according to the company report).
1935	VDE 0165 "Basic Principles for Setting up Electrical Systems in Hazardous Areas"
1943	VDE 0170/0171: first joint construction and testing "Requirements for Electrical Equipment Protected from Firedamp and Explosion V.43 or IV.44
1943	Police Regulation regarding Electrical Equipment in Hazardous Areas and Operating Systems, October 13, 1943
1945	Definition of the term "Intrinsic Safety" British Standard BS 1259: 1945
1956	Recognition of the principle of Intrinsic Safety in the USA ("National Electrical Code, 1956 Edition", National Fire Protection Association, Boston)
1957	Signing of the Rome Accords (Art. 100: Reduction of Technical Barriers to Commerce)
1963	Regulation regarding Electrical Systems in Hazardous Areas (ExVO), August 15, 1963
1965	First German Standard on Intrinsic Safety
1975	EC (Ex) General Directive (76/117/EEC), DecEMBER 18, 1975 for harmonising statutory requirements of member states regarding Electrical Apparatus for Potentially Explosive Atmospheres
1977	Approval of explosion protection requirements EN 50014 through EN 50020 of the CENELEC European Committee for Electrotechnical Standardisation
1978	Approval of European standardisation as DIN/VDE requirements 0170/0171
1980	Regulation regarding Electrical Systems in Potentially Explosive Atmospheres (ElexV), February 27, 1980; implementation of EC (Ex-) General Directive regulation into German law
1994	Guideline 94/9/EC of the European Parliament and Council, March 23, 1994 (ATEX 95)
1996	Implementation of ATEX 95 into national law leads to the Second Regulation on Device Safety Law related to Placing Devices and Protection Systems into Circulation for Areas Subject to the Danger of Explosions (Explosion Protection Regulation ExVO)
1996	Regulation regarding Electrical Systems in Hazardous Areas
1999	Directive 1999/92/EC of the Council for Minimum Requirements for Improving the Health Protection and Safety of Employees subject to Potentially Explosive Atmospheres (ATEX 137).
2002	Industrial Safety Regulation (BetrSichV)

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The Rome Accords were signed in 1957. Article 100a calls for the reduction of technical barriers to commerce between member nations. An important requirement for this was the harmonisation of safety-related standards and thus the integration of VDE requirements into a body of European standards. The most important milestones were in this integration were EC (Ex) General Directive 76/117/EEC, December 18, 1975, the approval of EN 50014 through EN 50020 in 1977 by CENELEC (The European Committee for Electrical Standardisation) and the approval of this EN in 1978 as DIN VDE requirements. Additional individual EC regulations follow these European standardisation activities.

This marks the creation of uniform law for the manufacturing of and commerce in electrical equipment for use in hazardous areas not only within the EC, but also beyond its borders (EFTA and other countries). However, installation requirements continued to the subject to statutory and administrative requirements of each individual country (see Directive 76/117/EEC).

In the meanwhile, two EC regulations have **fundamentally** changed the EC Ex landscape:

- **Directive 94/9/EC** of the European Parliament and Council of March 23, 1994 for harmonising statutory requirements of member nations for devices and protection systems intended for use in hazardous areas **(ATEX 95)**;
- **Directive 1999/92/EC** of the European Parliament and Council of December 16, 1999, regarding minimum requirements for improving health protection and safety of employees who may be endangered by a potentially explosive atmosphere **(ATEX 137)**.

ATEX 95 is fundamentally directed at manufacturers of electrical equipment and had to be implemented **word for word** into national law. This happened with the eleventh Regulation on the Device Safety Law (Regulation on Placing Devices and Protection Systems in Circulation for hazardous areas – **Explosion Protection Regulation** – 11th GSGV) dated December 12, 1996. On the following day, the Regulation on Electrical Systems in Potentially Explosive Atmospheres (ElexV) was published (without any of the requirements for required properties in terms of equipment).

ATEX 137 is directed at operators of electrical systems, devices and protection systems and must be implemented into national law **in accordance with its intended meaning**. This occurred in the form of the "Regulation for Simplification in the Areas of Safety and Health Protection in Providing Work Equipment and its use in Work, Safety in Operating Systems Requiring Monitoring and the Organisation of Health Protection" dated September 27, 2002.

Article 1 of this regulation contains the "Regulation regarding Safety and Health Protection in Providing Work Equipment and its use in Work, Safety in Operating Systems Requiring Monitoring and the Organisation of Industrial Work Protection" **(Industrial Safety Regulation – BetrSichV)**.

Since publication, the BetrSichV (German statute relating to operating safety) has been amended several times (Versions dated December 23, 2004, and July 07, 2005. Of these, the amendment dated December 12, 2004, has a sweeping effect on the execution of the testing of systems requiring monitoring in the hazardous area.

In accordance with § 24 of BetrSichV a committee for operating safety of the Ministry for Employment and Economics is charged with the task of devising regulations to ensure that the requirements of the BetrSichV can be fulfilled. Sub-committees have been formed to prepare technical rules for operating safety (TRBS) to be promulgated in the federal codes of practice/work sheets.

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Of these technical rules, those concerned with the major theme of "Explosion protection" include:

- TRBS 1111 "Risk assessment and safety evaluation",
- TRBS 1201 "Testing of operating means and plant requiring monitoring",
- TRBS 1203 "Competent persons" with the parts:
  - General requirements
  - Risk of explosion
  - Risk of over pressurization
  - Electrical risks,
- TRBS 2152 "Dangerous explosive atmospheres" with the parts:
  - General
  - Assessment of the risk of explosion
  - Avoidance or limitation of dangerous explosive atmospheres

These TRBS, which were published up to June 02, 2006, are discussed in greater detail in section 2.

Available as a "reading aid" for ATEX 95, there is a **guideline** for using Directive 94/9/EC of May 2000 and a non-binding **instruction manual** for ATEX 137 with proven procedures related to executing Directive 1999/92/EC (revised draft of October 2002).

Although this is not the place for a more detailed examination of transitional regulation the wide variety of EC directives and national regulations that have gone in and out of force, suffice it to emphasise that beginning July 1, 2003, ATEX 95 ATEX 137 determine EC law for explosion protection. Directive 76/117/EEC, Directive 79/196/EEC and Directive 82/130/EEC will be eliminated effective **July 1, 2003**. Thus uniform law applies beyond EC countries (for example Switzerland completely took over the terms of ATEX 95 on April 1, 1998, with the VGSEB regulation) for manufacturing and placing in circulation and installing devices and protection systems intended for use in hazardous areas.

To conclude this introduction, it should be noted that the scope of ATEX 95 also includes non-electrical devices and protection systems. The scope of ATEX 95 furthermore includes safety, regulating and control equipment for use outside of hazardous areas (see article 1 of the Directive). The ATEX guideline of May 2000 notes in this regard:

Attention

"It should be observed that Directive 94/9/EC specifies for the first time basic health and safety requirements for non-electrical devices intended for use in hazardous areas, for devices intended for use in areas in which there is a danger of explosion due to the formation of dust, for equipment intended for use outside of hazardous areas, and for safe operation of devices and protection systems related to or contributing to the risk of explosion". [3]

This enumeration of many directives and laws is by no means complete, and includes only the most important ones. Rules of the professional organisation will go unmentioned, for example BGR 104 Rules for Safety and Health Protection at Work (EX-RL) or BGR 132 Directive for Avoiding Risks of Ignition Resulting from Electrostatic Charges ("Static Electricity" Directive).

1.2 Legal basis before 2003

This section will briefly explain the legal situation in existence until the completion of the harmonisation of European law in the area of explosion protection. The time indicated, "before 2003" is deliberately imprecise since ATEX 95 and ATEX 137 took effect as they were implemented into national laws through ExVO and BetrSichV in steps between 1996 and 2003. Many national regulations were adapted during this period (modified), before they went out of force. The best example of this is ElexV.

It is important to note that whatever was previously good still remains so. No properly operated system needs to be refitted because of ATEX regulations. Even if Directives 76/117/EEC, 79/196/EEC and 82/130/EEC have been eliminated in accordance with article 14 of ATEX 95 as of July 1, 2003, the certificates (of conformity) issued on the basis of these directives remain valid in terms of proper use of this equipment (see article 14 Paragraph 3 of ATEX 95, § 7 Paragraph 2 of ExVO). The section on "Ignition Protection" deals with identification of devices not approved in accordance with ATEX 95. **Placing this equipment in circulation after July 1, 2003 is prohibited**.

The most important EC directives before application of ATEX 95 are listed below:

- **EC Ex General Directive (76/117/EEC), December 18, 1975**
  Valid until June 30, 2003
- **EC Ex Individual Directive (79/196/EEC)** of February 6, 1979
  A generation (line generation)
  In accordance with 1st generation European standards (1977/78 version)
- **EC Sch Directive (82/130/EEC) of February 15, 1982**
  Electrical equipment in mining systems above and below ground conducting minegas
- **EC Ex Individual Directive (84/87/EEC), January 16, 1984**
  Official introduction of changes introduced in European standards up to that point for technical reasons, **B generation**
- **EC Individual Directive (88/571/EEC)**, November 10, 1988 C generation in accordance with Adaptation Directive ATEX /III94/03 D generation
- **Directive 98/65/EC**, September 3, 1998, E generation

As of March 1, 1996, EC member nations have been using ATEX 95. On December 20, 1996 Explosion Protection Regulation ExVO went into effect in addition. ATEX 137 was published on December 16, 1999. As of October 3, 2003, it will be implemented into national law by the Industrial Safety Regulation relevant to explosion protection of September 27, 2002 (see article 8 of the Directive for Simplification of Law in the area of Safety and Health Protection in Providing Work Equipment and its use in Work, Safety in Operating Systems Requiring Monitoring and the Organisation of Health Protection"). As the heading of ATEX 137 clearly indicates, its main concern is health and work protection. This topic, which is directed to operators of systems, will be discussed in a later section.

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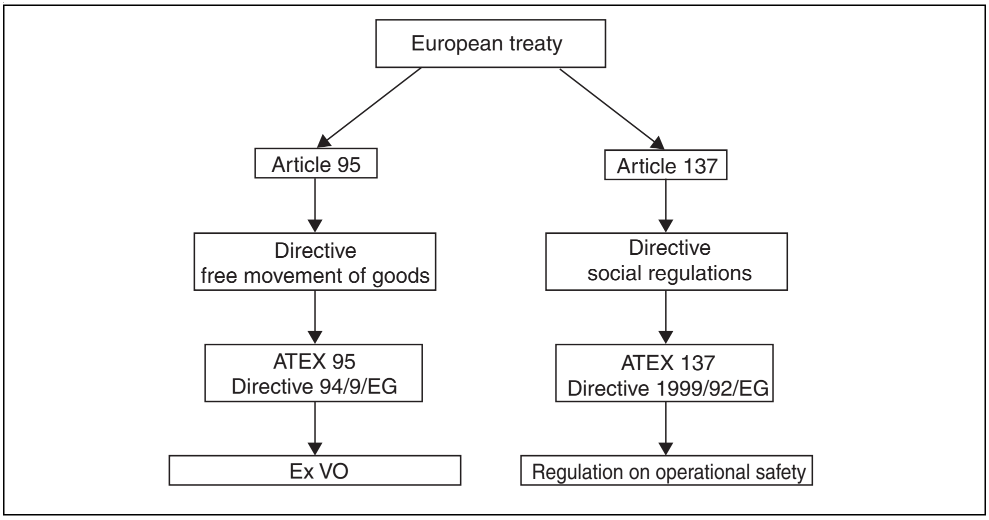

Figure 1.1 EC Directive and its implementation in national law

Article 95: Directive for standardising legal and administrative requirements of member states that have a direct effect on setting up the common market and how it operates

Goal: Reduction of technical barriers to commerce

Article 137: Member states shall endeavour to promote improvements, particular in the work environment to protect the safety and health of employees and shall set as a goal the harmonisation of conditions existing in this area together with progress.

Goal: Minimum requirements for improving the work environment

The following section deals in greater detail with ATEX 95, which is directed at manufacturers of equipment in its requirements for properties and specifications for placing items in circulation.

1.3 Directive 94/9/EC (ATEX 95)

1.3.1 Notes on the Directive 94/9/EC

The wording of ATEX 95 is included in the appendix. Excerpts are shortened or reflect only the general meaning of the original in the individual sections of this manual. We recommend detailed reading of the directive.

In a section roughly equivalent to a preface to the directive, the reasons are given that led to issuing the directive. Four of these reasons will be given below:

- *Within the individual member nations, requirements of differing scope and deviations in prescribed testing procedures result in dissimilarities that act as barriers to the free circulation of goods within the community. The only way to eliminate these barriers to free circulation of goods is to harmonise the legal requirements of the individual countries.*
- *It is absolutely essential to observe the basic requirements of the safety and health protection to ensure the safety of devices and equipment. These requirements must be implemented judiciously to take full account of the* ***state of the art*** *at the time when the devices are built.*
- *This directive therefore defines only* ***basic requirements****. To facilitate the task of demonstrating that a device meets these requirements, uniform standards must be created on a European level, especially for the* ***non-electrical area of explosion protection****.*
- *The task of developing the harmonised standards valid throughout Europe, which were not and still cannot be obligatorily prescribed, falls to private organisations. [4]*

Important matters of concern in addition to harmonisation are thus:

- Basic safety and health requirements for design and construction
- No obligatory application of the harmonised standards
- Implementing the state of the art at the time the devices are built
- Reference to the scope of validity including the non-electrical area of explosion protection.

ATEX 95 is subdivided into 4 chapters and contains 9 appendices:

Chapter I	Area of application, placing in circulation and free circulation of goods
Chapter II	Procedures for evaluating conformity
Chapter III	CE conformity mark
Chapter IV	Final stipulations
Appendix I	Decision criteria for subdividing device groups into categories
Appendix II	Basic safety and health requirements for designing and building devices and protection systems intended for use in hazardous areas
Appendix III/IX	Detailed specifications on the individual procedures for evaluating conformity

1.3.2 Chapter I – area of application, placing in circulation and free circulation of goods

A summarised overview of the area of application shows the following composition:

Application: Machines, electrical and non-electrical equipment, control and fitting parts, warning and preventive measures

Examples of affected devices, especially non-electrical devices: Fans, blowers, compressors, (vacuum) pumps, centrifuges, front-end loaders, lifting equipment, mechanical mills, vibration drives, stirring mechanisms including gear boxes and drive belts;

Examples of affected devices: Equipment, pipe lines, suction systems, fittings.

The most important content of article 1 is (for users to whom this manual is directed) the definition of device groups and device categories:

"Device group I applies to devices for use in below-ground mining operations as well as above-ground systems potentially endangered by minegas and/or combustible dust.

Device group II applies to devices for use in other areas that may be at risk due to a potentially explosive atmosphere." [4]

In other words: A device for Device group II can be used for Explosion group II.

Categorisation of devices into device categories is new in accordance with a required level of protection. The decision criteria for this are included in appendix I. Regardless of whether the devices to be used in areas subject to the danger of minegas or in areas subject to the danger of other gases or dusts are electrical or non-electrical, the fail-safe nature of the devices is the only criterion.

A device of Device category I of Device group II will serve as an example:

"Device group II, category 1"

Devices designed so that they can be operated in accordance with key rating data specified by the manufacturer and that ensure a high level of safety.

Devices of this category are designed for use in range where a potentially explosive atmosphere consisting of a mixture of air and gases, vapours or mist, or of dust/air mixtures is present constantly or long term or frequently.

Devices of this category must ensure the required level of safety with device malfunction occurring on an infrequent basis and therefore exhibit explosion protection measures so that if a protection measure based on technical equipment fails, there is at least one additional independent safety measure based on technical equipment that will ensure the required safety, or if two independent faults occur together the required safety will be ensured." [4]

If reference is made in these criteria to the presence of a potentially explosive atmosphere, it may be assumed there is a connection with Ex zones, although they are not explicitly mentioned in ATEX 95, since this directive is intended for manufacturers of devices. Since the devices are intended for use in an Ex zone at some time, however, the following table appears with a mixture of device groups, device categories and zones permitted in this place.

Device group	Device category	Probability of Ex atmosphere *	Measure of safety to be ensured *	Sufficient safety with *	Comparison to the previous categorisation of groups and zones
I (minegas, flammable dust)	M1	Present	Very high	2 faults 2 independent protection measures related to technical equipment	Explosion group I
	M2	Can be turned off when Ex atmosphere occurs	High	Ignition sources ineffective even under aggravated conditions	Explosion group I
II all other areas except I (mixtures of air and gases, vapours, mist and dust)	1	Constant, long-term or frequently present	Very high	2 faults 2 independent protection measures related to technical equipment	Explosion group II Zone 0 Zone 20
	2	Occasionally present	High	Avoidance of ignition sources for devices and operating malfunctions	Explosion group II Zone 1 Zone 21
	3	Not, or seldom and then only briefly	Usual	Normal mode	Explosion group II Zone 2 Zone 22

*) Detailed explanations of these columns may be found in:
Appendix I – Decision criteria for subdividing device groups into categories
Appendix II – Basic safety and health requirements for designing and building devices and protection systems intended for use in hazardous areas

Table 1.1 Assignment of device group, category and zone

Article 1 of the directive requires that basic safety and health requirements in accordance with appendix II be met as part of proper usage. The principles of explosion protection require the manufacturer to take measures:

- *"to give precedence wherever possible to avoiding potentially explosive atmospheres that can be generated or released by devices and protection systems themselves;*
- *to prevent the ignition of potentially explosive atmospheres, taking into consideration electrical and non-electrical sources of ignition in each individual case;*
- *if an explosion should occur that could endanger persons and domestic animals or goods either directly or indirectly, to stop it immediately and/or to limit the effective range of flames and pressure from the explosion to a sufficiently safe extent." [4]*

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In summary this means:

- Preventing the occurrence of potentially explosive atmospheres
  ⇒ **primary explosion protection**
- Preventing the ignition of a potentially explosive atmosphere
  ⇒ **secondary explosion protection**
- Stopping the expansion of an explosion that has occurred and limiting its effect
  ⇒ **tertiary explosion protection**.

Appendix II contains stipulations made to identify devices. However, this topic will be postponed until after ignition protection classes have been discussed. Suffice it to say at this point that there is a new identification in accordance with ATEX 95 and obligatory references to safety in use. These may be referred to as the "technical identification" in accordance with EN 50014.

Great significance is ascribed to the instruction manual (see appendix II, section 1.0.6):

An instruction manual must be present for each device or protection system, and must contain at least the following minimum information:

- The same information as required under identification
- Information on safe commissioning, use, mounting and dismounting, maintenance installation, and fitting
- Electrical rating data and pressures, the maximum surface temperature, etc. limiting values
- Other information.

Attention

During commissioning, the original instruction manual must be available in the community language (or language of the country where the device is being used).

If the devices makes reference to "special conditions for safe usage" with the letter "X" in the identification, this information must absolutely be available at the place where the device is to be used in the language of the relevant country.

1.3.3 Chapter II – procedures for evaluating conformity

Depending on proper use of the devices, i. e. their usage in accordance with device groups and categories (and thus for Device group II how they are assigned to Zones 0 or 20, 1 or 21, 2 or 22 as well according to the device categories), conformity procedures and combinations of them are prescribed to be able to affix the CE Mark.

These procedures are described in Appendices III to IX. There follows a list and summary of required combinations:

III EC type examination test
Basic requirement for device category M 1 and 1, M 2 and 2

IV Production quality assurance
required with III for M 1 or 1

V Test of products
required with III for M 1 or 1

VI Conformity with the design
required with III for M 2 or 2

VII Product quality assurance
required with III for M 2 or 2

VIII Internal manufacturing monitoring
Requirement for Device category 3

IX Individual test

Once the conformity evaluation has been successfully performed, the CE Mark can be given to the device. It is absolutely essential for all devices of Device category M 1 and 1 as well as all electrical devices of category M 2 and 2 that an EC Declaration of Conformity be on file for the device to be identified.

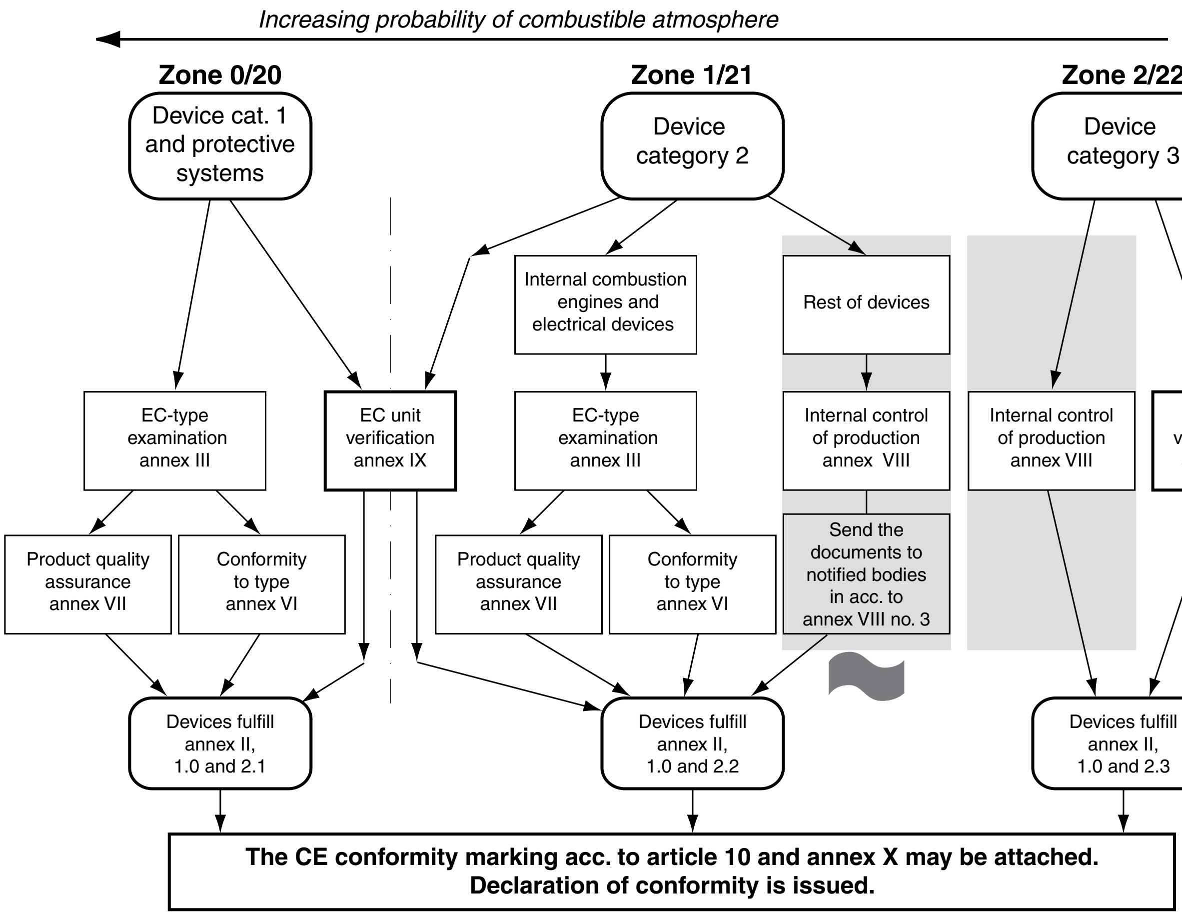

Figure 1.2 Evidence of conformity acc. to Directive 94/9/EC

It can be seen from Figure 1.2 [7], that

- all the apparatus to be installed in Zones 0 and 20 (category 1), i. e. including the non-electrical apparatus, must be subjected to an EU prototype test or individual EU test.
- The electrical apparatus for Zones 1 and 21, i. e. assigned to category 2, must also be subjected to an EU prototype test; but not, however, the non-electrical apparatus (the most important documentation here being the operating instructions).
- Electrical and non-electrical apparatus for Zones 2 and 22 (category 3) do not have to be subjected to an EU prototype test.

Physikalisch-Technische Bundesanstalt PTB

Braunschweig und Berlin

(1) **EC-TYPE-EXAMINATION CERTIFICATE**
(Translation)

(2) Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres - **Directive 94/9/EC**

(3) EC-type-examination Certificate Number:

PTB 98 ATEX 2210

(4) Equipment: Valve control unit type FD0-VC-Ex4.PA***

(5) Manufacturer: Pepperl + Fuchs GmbH

(6) Address: Königsberger Allee 87, D-68307 Mannheim

(7) This equipment and any acceptable variation thereto are specified in the schedule to this certificate and the documents therein referred to.

(8) The Physikalisch-Technische Bundesanstalt, notified body No. 0102 in accordance with Article 9 of the Council Directive 94/9/EC of 23 March 1994, certifies that this equipment has been found to comply with the Essential Health and Safety Requirements relating to the design and construction of equipment and protective systems intended for use in potentially explosive atmospheres, given in Annex II to the Directive.

The examination and test results are recorded in the confidential report PTB Ex 98-28034.

(9) Compliance with the Essential Health and Safety Requirements has been assured by compliance with:

EN 50014:1997 **EN 50020:1994**

(10) If the sign "X" is placed after the certificate number, it indicates that the equipment is subject to special conditions for safe use specified in the schedule to this certificate.

(11) This EC-type-examination Certificate relates only to the design and construction of the specified equipment in accordance with Directive 94/9/EC. Further requirements of this Directive apply to the manufacture and supply of this equipment.

(12) The marking of the equipment shall include the following:

II (1) 2 G EEx ia IIC T4

Zertifizierungsstelle Explosionsschutz
By order:

(signature)

Dr.-Ing. U. Johannsmeyer
Regierungsdirektor

Braunschweig, December 18, 1998

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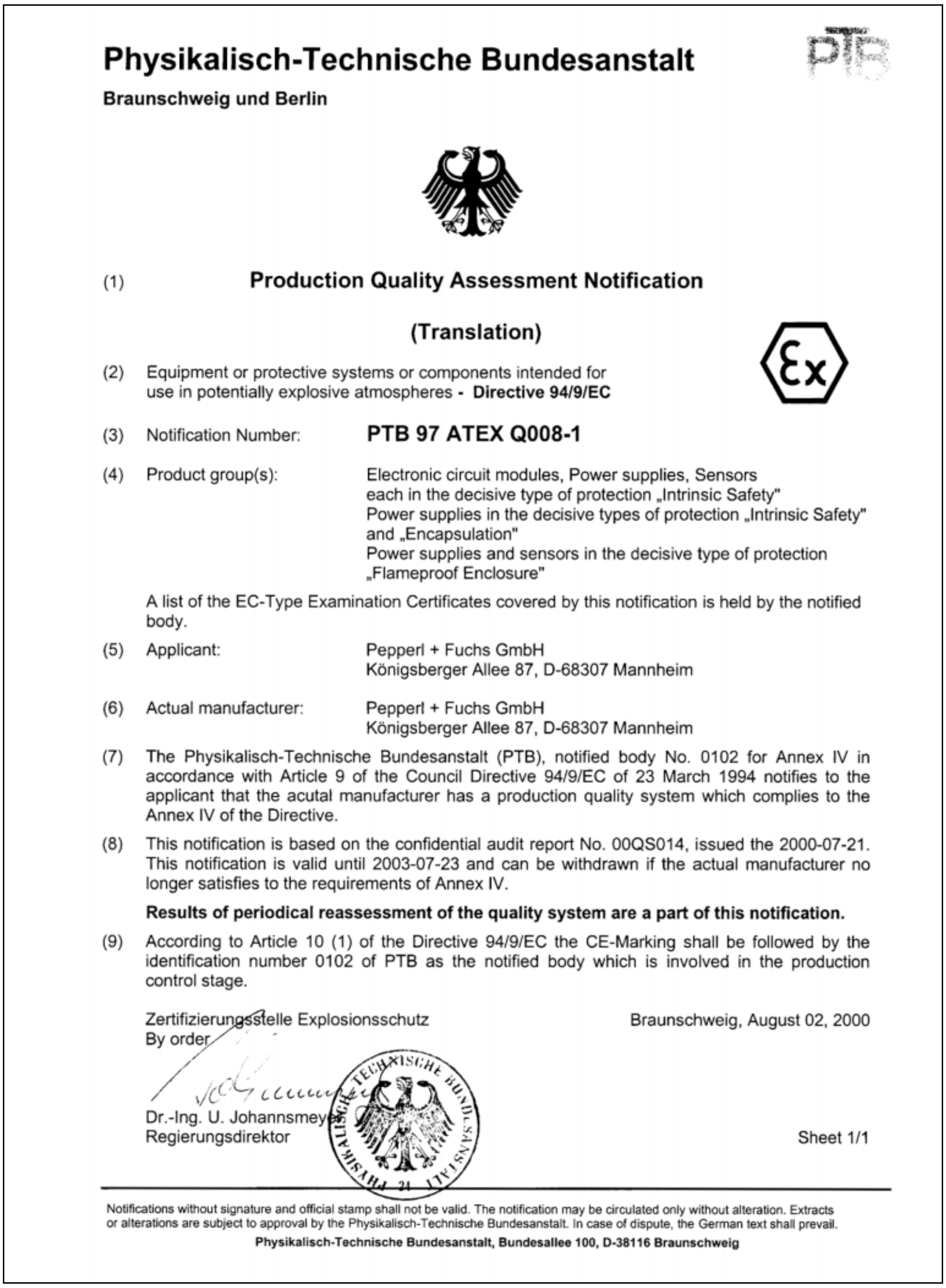
EC-type-examination Certificates without signature and official stamp shall not be valid. The certificates may be circulated only without alteration. Extracts or alterations are subject to approval by the Physikalisch-Technische Bundesanstalt. In case of dispute, the German text shall prevail.

Physikalisch-Technische Bundesanstalt • Bundesallee 100 • D-38116 Braunschweig

Figure 1.3 EC Type Examination Certificate

A "named location" as defined by article 9 of ATEX 95 must perform the test and issue the certificate. A list of such locations appears in the official publication of the European Communities. These include, among others PTB, DMT, TÜV of Rheinland, Berlin, Brandenburg and IBExU.

PTB or other named locations also audit the manufacturer. Provided the production quality assurance system has been approved by this supervisory audit, the quality assurance system of Pepperl+Fuchs GmbH meets the requirements of appendix IV of ATEX 95. Thus electrical devices of categories 1 and 2 can be manufactured, identified according to individual tests, and placed in circulation.



Physikalisch-Technische Bundesanstalt

Braunschweig und Berlin

PTB

(1) **Production Quality Assessment Notification**

(Translation)

(2) Equipment or protective systems or components intended for use in potentially explosive atmospheres - **Directive 94/9/EC**

(3) Notification Number: **PTB 97 ATEX Q008-1**

(4) Product group(s): Electronic circuit modules, Power supplies, Sensors each in the decisive type of protection „Intrinsic Safety" Power supplies in the decisive types of protection „Intrinsic Safety" and „Encapsulation" Power supplies and sensors in the decisive type of protection „Flameproof Enclosure"

A list of the EC-Type Examination Certificates covered by this notification is held by the notified body.

(5) Applicant: Pepperl + Fuchs GmbH
Königsberger Allee 87, D-68307 Mannheim

(6) Actual manufacturer: Pepperl + Fuchs GmbH
Königsberger Allee 87, D-68307 Mannheim

(7) The Physikalisch-Technische Bundesanstalt (PTB), notified body No. 0102 for Annex IV in accordance with Article 9 of the Council Directive 94/9/EC of 23 March 1994 notifies to the applicant that the acutal manufacturer has a production quality system which complies to the Annex IV of the Directive.

(8) This notification is based on the confidential audit report No. 00QS014, issued the 2000-07-21. This notification is valid until 2003-07-23 and can be withdrawn if the actual manufacturer no longer satisfies to the requirements of Annex IV.

Results of periodical reassessment of the quality system are a part of this notification.

(9) According to Article 10 (1) of the Directive 94/9/EC the CE-Marking shall be followed by the identification number 0102 of PTB as the notified body which is involved in the production control stage.

Zertifizierungsstelle Explosionsschutz
By order

Braunschweig, August 02, 2000

Dr.-Ing. U. Johannsmeyer
Regierungsdirektor

Sheet 1/1

Notifications without signature and official stamp shall not be valid. The notification may be circulated only without alteration. Extracts or alterations are subject to approval by the Physikalisch-Technische Bundesanstalt. In case of dispute, the German text shall prevail.

Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

Figure 1.4 Product quality assessment notification

In addition to the stipulations for CE conformity identification (Chapter III), ATEX 95 contains the key specifications in chapter IV. The most important of these are listed below:

- July 01, 2003: Directive 76/117/EEC, 79/196/EEC, 82/130/EEC are eliminated
- June 30, 2003: the latest possible validity date of existing certificates of conformity,
- Interim regulation for equipment already approved before July 1, 2003 in accordance with 94/9/EC.

1.4 Implementation of ATEX 95 by way of Explosion Protection Regulation ExVO

ATEX 95 took effect on March 1, 1996. It was implemented into national law through the Eleventh Regulation following the Device Safety Law (Regulation on placing devices and protection systems in circulation for hazardous areas – Explosion Protection Regulation – 11.GSGV). ExVO took effect on December 20, 1996.

The wording of this Regulation appears in the appendix. Following some of its most important content is quoted or paraphrased.

§ 1 lists the following under area of application:

- *"Devices and protection systems for proper use in hazardous areas*
- *Safety, monitoring and control equipment for use outside of hazardous areas, but which are required for or contribute to safe operation of devices and protection systems in reference to the dangers of explosion*
- *Components that are required to be built into the devices and protection systems listed above." [5]*

The definitions of terms in § 2 refer in some cases to device groups and device categories:

(6) According to the intended purpose, devices are ... subdivided into **Device groups** to which ... **Device categories** are assigned depending on the level of protection required.

(7) **Indended use** is the use of devices, protection systems and equipment .... **in accordance to the device group and category** and taking into consideration all manufacturer's information required for safe operation.

§ 4 lists the requirements for placing devices in circulation:

- Identification (maintaining numerous conditions)
  Ex components do not include any CE Mark
  CE Mark also includes requirements that go beyond Ex protection
- Declaration of conformity must be enclosed
- Instruction manual must be enclosed
- Procedures in accordance with Appendices III to IX ATEX 95 must be fulfilled.

One noteworthy feature should be pointed out here. When ExVO entered into force, all requirements related to the nature of electrical equipment were stricken from ElexV as well § 10 ElexV "Specially prepared devices".

ExVO contains in § 4 section 5, as a direct implementation of article 8 section 5 of ATEX 95, a provision for exception from the conformity procedure. Based on a well-founded application of the manufacturers, responsible national authorities (for example labour inspectors) can approve placing of devices, protection systems or devices in circulation and commissioning them on the level of the member state without the conformity procedures defined in Appendices III through IX. This stipulation is intended for placing individual devices or specially prepared devices in circulation (for example pressurising systems).

The ExVO explains this as follows:

"Contrary to the requirements listed in §4 for placing devices in circulation, responsible authorities may approve, based on well-founded application, ***placing in circulation*** *of devices, protection systems and equipment ...... , to which the procedures cited in Paragraph 1 No. 1 letter b (fulfillment of Appendices III through IX of Directive 94/9/EC) are not applied if they are being provided for use in the interest of safety". [5]*

Similarly to ATEX 95, the interim stipulations in § 7 specify:

"Devices and protection systems that meet requirements applicable to this scope of validity on March 24, 1994 may be placed in circulation until ***June 30, 2003*** *."*

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1.5 Directive 1999/92/EC (ATEX 137)

In contrast to ATEX 95 with its requirements for features, ATEX 137 is directed not at device manufacturers, but rather at operators. This is clear simply from the title of this directive:

Directive concerning Minimum Requirements for Improving the Health Protection and Safety of Employees who may be exposed to Potentially Explosive Atmospheres.

The main points of ATEX 137 are:

- Classification of areas in which a dangerous, potentially explosive atmosphere may be present (evaluation of explosion risks, providing and determining safety-related ratings data),
- Determining which devices and protection systems can be used in the respective zones and the criteria for selecting equipment and installation material for the different zones
- Creating and continuously updating an explosion protection document
- Marking areas in which a potentially explosive atmosphere may occur at a level endangering safety at access points to them
- Determining criteria for approving jobs in various zones.

Article 9 "Special requirements for equipment and work sites" specifies a number of points including the following:

- Work equipment already being used or made available for the first time before June 30, 2003 must meet minimum requirements (appendix II, section A) if no other community regulation is applicable (ATEX 95 supersedes previous EC requirements related to B ... E generation as of June 30, 2003).
- Work equipment made available for the first time after June 30, 2003 must meet the requirements of appendix II, section A and B (section B determines the use of devices of categories 1, 2 , 3 in zones 0/20, 1/21 and 2/22).

Appendix I of ATEX 137 divides the hazardous areas into zones.
"An area in which a potentially explosive atmosphere may occur in quantities such that special safety measures are required to maintain the protection of safety and health of employees who are involved is considered an ***hazardous area****.*

These area are subdivided into zones depending on the frequency and duration of occurrence of a potentially explosive atmosphere." [6]

Further specific details of ATEX 137 and how they are implemented by the Industrial Safety Regulation BetrSichV will be discussed in the following section.

The definitions of zones as specified in appendix I of ATEX 137, valid throughout Europe, together with the specification of criteria for selecting devices and protection systems in accordance with section B of appendix II of ATEX 137 and the decision criteria for device groups in categories in accordance with appendix I of ATEX 95, constitutes a key body of requirements for unambiguously assigning devices to zones. The intent was to replace this with new and revised European standards as defined in the legal requirements of the individual countries discussed in the preface to ATEX 95.

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1.6 Implementation of ATEX regulations through European standards

This section will cite European standards and their draft versions as well as national requirements, especially those related to non-electrical explosion protection, which had to be modified to implement the ATEX directives. This section is concerned only with the body of requirements for Device group II and thus Explosion group II. The list of standards is not complete, since with the implementation of ATEX directives a large number of new standards or standards in draft version have been presented, especially regarding dust explosion protection, but also non-electrical explosion protection.

With the implementation of ATEX 95, the following standards in particular may be noted in the area of electrical explosion protection:

Electrical apparatus for areas where there is a risk of a gas explosion:

- EN 50014/ IEC 60079-0 — General definitions
- EN 50015 ... 39/ IEC 60079-1 ... 25 — Standards relating to the types of ignition protection
- DIN EN 60079-26 — Electrical apparatus group II, 1G

Electrical apparatus for use in areas with combustible dust:

- DIN EN 61241-0 — General requirements
- DIN EN 61241-1/2/ 11/18 — Dust ignition protection types tD, pD, iD, mD

The following standards are relevant to the non-electrical devices for use in areas endangered by the risk of explosion/hazardous areas:

- EN 13463-1 — Underlying methodology and requirements
- EN 13463-5/6/8 — Protection through constructional safety "c"/ignition source monitoring "b"/ liquid enclosure "k"
- Other draft standards
- DIN EN 1834-1 ... 3 — Safety requirements for the design and construction of reciprocating internal combustion engines/industrial vehicles for use in hazardous areas
- DIN EN 12874 — Flame protectors, energy requirements, test methods and limitations of use
- EN 1010-1 — Printing and paper converting machinery
- VDMA 24169 — Recommendations for fans for the delivery of combustible gases, vapours and atmospheres containing mist.

The following standards and regulations are related to the scope of ATEX 137:

- EN 1127-1 — Explosive atmospheres – explosion protection, fundamentals and methodology
- BGR 104 — Explosion protection rules (currently being integrated into TRBS 2152)
- BGR 132 — The avoidance of the danger of ignition due to electrostatic charging
- DIN EN 60079-14/ IEC 60079-14 — Electrical apparatus for areas made hazardous by the risk of gas explosion; electrical systems in hazardous areas
- DIN EN 61241-14 — Electrical apparatus for use in areas with combustible dust – Selection and installation
- DIN EN 60079-10 — Electrical apparatus for areas made hazardous by the risk of gas explosion; classification of the hazardous areas

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- DIN EN 61241-10 Electrical apparatus for use in areas with combustible dust; classification of the hazardous areas
- DIN EN 60079-17 Electrical apparatus for areas made hazardous by the risk of gas explosion; testing and maintenance of electrical systems in hazardous areas
- DIN EN 61241-17 Electrical apparatus for areas made hazardous by the risk of gas explosion; inspection and maintenance of electrical systems in hazardous areas

The above listing of the standards and regulations is incomplete. It should also be noted, that many EN standards are converted to IEC standards and that the assimilation of the control documentation for the gas and dust hazardous area is ongoing.

So as not to leave the impression that this (incomplete) list of standards, requirements and rules represents the body of requirements for explosion protection, there follows here a list (also not complete) of other important VDE requirements that must be observed for explosion protection:

- DIN VDE 0100 Setting up high-voltage systems with nominal voltages up to 1000 V
- DIN VDE 0100, part 540 Setting up high-voltage systems with nominal voltages up to 1000 V; selecting and setting up electrical equipment grounding, protective conductors, potential compensation lines

The relevant chapters contain detailed discussions of the standards cited here.

1.7 References

[1] Prof. Dr. Eng. H. Dreier/Prof. Dr. Eng. K.-H. Gehm
40 Years of Explosion Protection in the PTB, PTB publication 5/1987

[2] Presentation of Cert. Eng. J. Huber, Bavarian State Government, "The legal basis of explosion protection"

[3] ATEX guidelines (first edition) guidelines on using Directive 94/9/EC of March 23, 1994

[4] Directive 94/9/EC of the European Parliament and Council of March 23, 1994 for harmonising statutory requirements of member nations for devices and protection systems intended for use in hazardous areas (ATEX 95);

[5] Eleventh regulation on the device safety law (regulation on placing devices and safety systems in circulation for hazardous areas – explosion protection regulation – 11. GSGV)

[6] Directive 1999/92/EC of the European Parliament and Council of December 16, 1999 regarding minimum requirements for improving health protection and safety of employees who may be endangered by a potentially explosive atmosphere (ATEX 137).

[7] Presentation of TÜV SÜD Akademie GmbH "Legal background of Directive 94/9 EC"

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2 Implementation of ATEX 137 by way of the Industrial Safety Regulation

2.1 Preliminary remarks

The following section deals with the "Regulation for Legal Simplification in the Area of Safety and Health Protection in Providing Work Equipment and its use in Work, Safety in Operating Systems requiring inspection and the Organisation of Work Protection" dated September 27, 2002.

This regulation is referred to as an article regulation consisting of a total of eight articles.

With article 1, the "Regulation concerning safety and health in providing work equipment and using it in work, concerning safety during operation of systems requiring inspection and concerning the organisation of industrial work protection (Industrial Safety Regulation BetrSichV)" Directive 1999/92/EC, referred to as ATEX 137, was implemented into national law along with a few other European directives.

The following sections describe primarily the requirements for operators of systems in potentially explosive atmospheres derived from the Industrial Safety Regulation. Changes in the Industrial Safety Regulation of December 23, 2004 are taken into consideration.

Since the minimum requirements from ATEX 137 are entirely incorporated in the Industrial Safety Regulation, it is no longer necessary to consider the EU directive in greater detail.

Likewise, article 2 (the Aerosol Packaging Regulation), 3 (Pressure Device Regulation), 4 (Pipeline Regulation) and 5 (modification of headings from regulations in the regulations for the Device Safety Law) will not be further discussed at this point, since they are not relevant for industrial explosion protection.

On the other hand, article 6, by which the Hazardous Substance Ordinance was changed, is of interest for industrial explosion protection.

Among other changes, appendix V (special requirements for certain hazardous substances and activities) of the Hazardous Substance Regulation was expanded. section No. 8 "Fire and explosion dangers" has been added. The requirements described there are also described below.

Article 7 contains the change to the Workplace Regulation by way of addition of protection for non-smokers and thus is of no significance to industrial explosion protection.

Article 8 regulates how the regulation will take effect and how the regulations replaced by the individual articles will loose their effect.

Accordingly, the **Industrial Safety Regulation** has been **binding** since **January 1, 2003** for operating systems requiring inspection (including systems in potentially explosive atmospheres.

Regulations in force up until this date, such as the "Regulation concerning electrical systems in potentially explosive atmospheres – ElexV", the "Regulation concerning flammable liquids – VbF" and the "Acetylene regulation" are rendered invalid by article 8.

In addition to the regulations listed here, other statutory requirements have also been abolished by the BetrSichV. These include the Steam Boiler Regulation, the Pressure Container Regulation, the Elevator Regulation, the Beverage Dispensing System Regulation and the work equipment Usage Regulation.

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The requirement from the Industrial Safety Regulation that an explosion protection document must be created to operate systems in potentially explosive atmospheres is of great significance for the area of explosion protection. Since this not only applies to new systems (since Oct. 03, 2002) but must also be on file for old systems as well (set up before Oct. 03, 2002) by December 31, 2005, a sample breakdown of contents of an explosion protection document is illustrated in a separate section.

Since great significance is also placed on testing and maintaining systems in potentially explosive atmospheres in accordance with the BetrSichV, DIN EN 60079-17 (VDE 0165, part 10) "Electrical equipment for explosive gas atmospheres part 17: Testing and maintaining electrical systems in potentially explosive atmospheres (except for mining construction)" will be discussed in greater detail.

2.2 The Industrial Safety Regulation

In the last few years, numerous EC directives for placing products in circulation (including ATEX 95) have displaced national requirements with European requirements for properties of products. This is significant in the area of explosion protection through changes in ElexV and VbF, both dated December 13, 1996. All paragraphs in which requirements for properties of equipment were described were stricken in these regulations.

Requirements for properties of products have been regulated since December 12, 1996 in the Explosion Protection Regulation ExVO, which was implemented into national law by Directive 94/9/EC (ATEX 95).

The minimum requirements for improving the work environment were also harmonised on a European level (article 137). The Industrial Safety Regulation is pursuing three main goals through this:

- Implementation of a number of EC directives into national law
- A uniform industrial system safety law with clear separation of physical conditions vs. operation as well as reassignment in the area of systems requiring inspection and
- Reassignment of the relationship between national law related to work equipment and trade union accident protection requirements, so as to eliminate existing double regulations.

The Industrial Safety Regulation describes a comprehensive protection concept that can be applied to all dangers caused by work equipment.

The basic elements of this protection concept are a uniform evaluation of risks or a safety-related evaluation for operating systems requiring inspection, the "state of the art" as a uniform safety standard, suitable protective measures and tests as well as minimum requirements for the physical features of work equipment.

The Industrial Safety Regulation is divided into four section. These sections will be discussed below in greater detail, with the focus of attention on requirements related to industrial explosion protection.

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2.2.1 Section 1: General requirements (§§ 1 and 2)

§ 1 – Range of application

The first paragraph describes how the Industrial Safety Regulation applies very generally to work equipment provided by employers and to the use of work equipment by employees for work.

Thus the requirements of the work equipment Usage Regulation were taken over. As mentioned above, the regulation itself is no longer in force.

The second paragraph of § 1 extends the scope of validity of the Industrial Safety Regulation to systems requiring inspection in accordance with § 2 Paragraph 2a of the Device Safety Law, provided the devices are

- Steam boiler systems, pressure container systems other than steam boilers, filling systems, leads under internal excess pressure for ignitable, readily ignitable, highly ignitable, corrosive or toxic gases, vapours or liquids
- Elevator systems
- Equipment in hazardous areas or
- Storage systems with an overall volume of more than 10,000 litres, filling and emptying stations with a transfer capacity of more than 1000 litres, service stations and airfield fuel tank systems if ignitable, readily ignitable or highly ignitable liquids (classification based on the Hazardous Substance Regulation, but see also section 3.3) are being stored or transferred from one container to another.

In addition to the general requirements of section 2 of the Regulation (§§ 3 to 11), the special requirements of section 3 (§§ 12 to 23) also apply to systems requiring inspection that are provided by an employer or that are used by employees for work.

If a system requiring inspection is not provided by an employer or is not used by employees for work, then the requirements of section 2 (§§ 3 to 11) do not apply to these systems.

All other requirements of the Industrial Safety Regulation (sections 1, 3 and 4) must of course be applied to these systems.

Paragraphs 3 through 6 of § 1 describe the systems to which the Industrial Safety Regulation does not apply.

These are on the one hand filling systems that are power systems as defined by the Power Production Law and are set up and operated on the operating grounds of public gas supply companies. On the other hand, the Industrial Safety Regulation does not apply to operations subject to German Federal legislation and to ocean-going ships under a foreign flag.

Furthermore, requirements of German Federal and state immission protection law, traffic law and nuclear law are unaffected by this regulation, provided other or more extensive requirements are made or approved in them. The German Federal Ministry of Defense can also have exceptions to the requirements of this requirements approved if this is required for urgent reasons and safety is ensured some other manner.

§ 2 – Definition of terms

The first paragraph defines the term **work equipment**. It is clear from the definition that a work equipment can be either a simple manual device or a complex system used in a process. The bandwidth thus extends from a pencil to complex manufacturing lines.

What is emphasized above all else is that the mutual effects of individual functional units that are connected with each other must be taken into consideration in evaluating systems. This is especially true in the case of systems requiring inspection.

Paragraph 2 contains the statement that **"providing"** work equipment also includes mounting and installation tasks for assembly and reliable use of the work equipment.

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According to Paragraph 3, the term **"use"** of a work equipment includes testing, placing in motion, stopping, making use of, repairing and maintaining, testing, safety measures for operating malfunctions, converting and disassembling and transporting.

"Operation of a system requiring inspection" means in accordance with Paragraph 4 operation as defined by Paragraph 3 with the exception of testing before first placing the system in service, disassembling and transport. Of course the test must be conducted by an approved inspection agency in this case.

Paragraphs 5 and 6 explain the terms **"modification of a system requiring inspection"** and "significant modification to a system requiring inspection".

A **"modification to a system requiring inspection"** is any measure that affects the safety of the system. Thus a "modification" as defined by the Industrial Safety Regulation means what was earlier referred to as a "Significant modification".

A **"significant modification of a system requiring inspection"** is any modification that changes the system sufficiently that in terms of safety it corresponds to a new system. The requirements for new technical work equipment must be used for such a system in accordance with the Device Safety Law.

Paragraph 7 describes the requirements for a **"qualified person"**. According to it, the "qualified person" must have the necessary technical knowledge to test the work equipment work equipment by virtue of professional training, professional experience and recent professional activity.

Especially for the area of systems in potentially explosive atmospheres and here for the more specific area of electrical systems, this means that not every specialist electrician is automatically considered a qualified person for testing work equipment as defined by this regulation. Since the activity of the qualified person as defined by the Industrial Safety Regulation, in addition to recent professional activity, requires above all else a knowledge of special requirements in force for these area, it is indispensable for an electrician who is becoming active in this area to become informed about current requirements and standards related to the state of the art through additional training and reading.

The requirements for qualified persons are described in the Technical Rules for Industrial Safety TRBS 1203 of November 18, 2004.

There are three different types of qualified persons for the area of explosion protection. For simplicity sake, the different types will be referred to here as in BGR 104, as type A, type B and type C.

Qualified persons of type A are authorised to test devices, protection systems as well as safety, monitoring and control equipment as defined by ATEX 95. A system in hazardous areas can also be tested by this type of qualified person in accordance with the change in the BetrSichV (Industrial Safety Regulation) of December 23, 2004 if the system is composed of devices, protection systems and safety, monitoring and control equipment as defined by ATEX 95 (see § 14 paragraph 3).

A qualified person who is authorised to test a system in hazardous areas is a person who in accordance with TRBS 1203:

1. on the basis of his or her technical training will ensure that the tests are performed properly and who has at least one year's experience in manufacturing, assembling or maintaining systems in hazardous areas or system components
2. possesses the necessary personal reliability
3. is not subject to any inappropriate instructions in terms of test activities
4. if necessary, has suitable testing equipment and
5. can demonstrate through successful participation in appropriate training that he or she has the necessary knowledge of the individual details of explosion protection as well as the relevant rules, and keeps this knowledge current.

Employees of approved monitoring centres who are approved for testing systems in hazardous areas also meet the requirements of qualified persons of type A.

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A qualified person of type B must be recognised by the responsible authorities and is approved for testing devices and protection systems as well as safety, monitoring and control equipment (see § 14, Paragraph 6). The requirements correspond to those of type A, but to receive official recognition, the person must have at least one year of experience with manufacturing or maintaining devices, protection systems and safety, monitoring and control equipment as defined by ATEX 95.

A qualified person of type C must have specific knowledge in the area of explosion protection and is permitted to test workplaces in hazardous areas in accordance with section 3.8 of appendix 4 of the BetrSichV (Industrial Safety Regulation). As part of testing work places, a test of the overall concept must be conducted including organizational measures.

In accordance with TRBS 1203, a qualified person with special knowledge in the area of explosion protection is someone who

1. on the basis of his or her technical training (applicable studies, applicable training as a technician or many years of professional experience in the area of safety technology) and extensive knowledge of fire and explosion protection is able to ensure that he or she will conduct tests properly
2. possesses the necessary personal reliability
3. is not subject to any inappropriate instructions in terms of test activities
4. if necessary, has suitable testing equipment and
5. participates regularly in appropriate exchanges of information and experience in the area of explosion protection.

The definition of the types A, B, C is not contained in TRBS, but is contained in the newer versions of BGR 104 and is frequently used to differentiate between the various competent persons.

The committee for operating safety (ABS) has decided, that the text portion of the Ex-RL should be inserted in the technical rules for operating safety without the appendices and without the collection of examples. The future structure of the text portion of the Ex-RL is planned as follows:

• TRBS 1203	Competent persons
• TRBS ****	Tests
• TRBS 2152	Dangerous explosive atmospheres – Fundamentals
• TRBS 2152, part 1	Dangerous explosive atmospheres – Assessment of the risk of explosion
• TRBS 2152, part 2	Dangerous explosive atmospheres – Avoidance of, or limitation of the formation of dangerous explosive atmospheres
• TRBS 2152, part 3	Dangerous explosive atmospheres – Avoidance of the ignition of dangerous explosive atmospheres
• TRBS 2152, part 3	Dangerous explosive atmospheres – Constructional measures, which limit the effects of an explosion to a level that can be considered to present a negligible risk (Constructional explosion protection)
• TRBS 2154	Explosion protection document
• TRBS 2155	The application of process control technology in the context of explosion protection measures
• TRBS 2156	Protection measures during maintenance work
• TRBS 2157	Organizational measures

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The TRBS 2152 fundamentals and also part 1 and 2 have already been published on June 2, 2006. It is possible, that TRBS **** mentioned above corresponds to TRBS 1201 "Testing of operating means and plant requiring monitoring".

The previous Ex-RL will be retained in its scope with the appendices 1 ... 5, which also contain a collection of examples.

Certain employees of approved monitoring centres who are approved for testing systems in hazardous areas also meet the requirements of qualified persons of type C.

Terms that are especially important for explosion protection are explained in Paragraphs 8 through 10. The content of these definitions is adapted to well-tried and tested national definitions (for example from the explosion protection rules of BG Chemie – BGR 104). They are cited here word for word:

(8) A **potentially explosive atmosphere** as defined by this regulation is a mixture of air and flammable gases, vapours, mist or dust under atmospheric conditions in which the combustion process is transferred to the entire unburnt mixture after ignition has occurred.

(9) A **dangerous potentially explosive atmosphere** is a potentially explosive atmosphere that occurs in such a quantity (dangerous quantity) that special safety measures are required to maintain the protection of safety and health of employees or others.

(10) **Hazardous area** as defined by this regulation is an area in which dangerous potentially explosive atmospheres can occur. An area in which a potentially explosive atmosphere cannot be expected in sufficient quantity that special protective measures are required is not considered a potentially hazardous area.

Paragraphs 11 through 19 of § 2 contain definitions of terms for other systems requiring inspection such as storage facilities, filling and emptying stations, service stations, elevators, etc. They will not be discussed in any greater detail here.

It should be noted, however, that certain systems requiring inspection such as storage systems or service stations as defined by this regulation may also contain hazardous areas.

2.2.2 Section 2: General requirements for work equipment (§§ 3 through 11)

§ 3 – Evaluation of danger

The first paragraph explains that in evaluating the danger, which must be performed in accordance with § 5, the employer must determine measures required to safely provide work equipment and allow for its use. He must also take into consideration mutual effects of work equipment on each other as well as work equipment with work substances or the work environment.

If the formation of a dangerous potentially explosive atmosphere is not safely prevented, the employer must, in accordance with Paragraph 2, evaluate the probability and duration of the occurrence of a dangerous potentially explosive atmosphere, the probability of the occurrence, activation and effectiveness of ignition source including electrostatic discharge, and the extent of the effects of the explosions to be anticipated.

The requirement according to Paragraph 3 specifies that the employer must stipulate the nature, extent and times of the required tests as part of the risk evaluation. He must also describe the requirements for the staff members he has entrusted with tests or trial runs.

§ 4 – Requirements for providing and using work equipment

The first paragraph describes the requirement in general that work equipment made available to employees by the employer must be suitable for all conditions that will be encountered at the workplace. The work equipment must not endanger the safety and health of employees. If this cannot be completely ensured, suitable measures must be taken by the employer to keep dangers as minor as possible.

In accordance with Paragraph 2 of § 4, when providing work equipment or if work equipment is used by employees, the employer must consider both his own risk evaluation in accordance with § 3 as well as the rules and knowledge determined by the Committee for Industrial Safety and published by the German Federal Ministry for Work Social Order.

The employer must also ensure in accordance with Paragraphs 3 and 4 that work equipment is only used if it is suitable for the intended application and if the ergonomic relationships between the workplace, work equipment, work organisation, work process and work task have been considered in sufficient detail.

§ 5 – Hazardous areas

The first paragraph requires the employer to categorise potentially explosive atmospheres into zones, taking into account the danger evaluation.

The different zones are defined in appendix 3 of the Industrial Safety Regulation:

Zone 0

is an area in which a potentially explosive atmosphere as a mixture of air and flammable gases or mists is present permanently, over long periods of time, or frequently.

Zone 1

is an area in which a potentially explosive atmosphere may occur occasionally during normal operation as a mixture of air and flammable gases, vapours or mists.

Zone 2

is an area in which a dangerous potentially explosive atmosphere as a mixture of air and flammable gases, vapours or mists does not occur normally or is only of brief duration.

Zone 20

is an area in which a dangerous atmosphere capable of exploding is present in the form of a cloud made up of combustible dust that is part of the air permanently, over long periods of time or frequently.

Zone 21

is an area in which a dangerous atmosphere capable of exploding may occur occasionally in the form of a cloud made up of flammable dust that is part of the air.

Zone 22

is an area in which a dangerous atmosphere capable of exploding may occur in the form of a cloud made up of combustible dust that is part of the air. This does not occur normally or is only of brief duration.

The second paragraph contains the requirement that the employer must ensure that the minimum requirements of appendix 4 of the Industrial Safety Regulation are being applied.

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Appendix 4 of the Industrial Safety Regulation is divided into part A "Minimum requirements for improving the safety and health protection of employees who may be endangered by dangerous potentially explosive atmosphere" and part B "Criteria for selecting devices and protection systems".

Part A of appendix 4 describes the organisational measures to be initiated by the employer, such as instructing employees, written instructions, work releases, supervision an applying warning and prohibition symbols.

According to it, potentially explosive atmospheres must be identified with a warning sign:

Figure 2.1 Identification of potentially explosive atmospheres and areas in accordance with Directive 1999/92/EC

Furthermore, additional explosion protection measures are listed, such as visual or acoustic warnings for staff members before explosion conditions are reached as well, taking into consideration electrostatic discharges as possible ignition sources. Reference is also made to the necessity of escape and rescue routes as well as exits being present in sufficient number and to providing escape materials if this is required in accordance with the danger evaluation.

There is further a requirement that work equipment used in potentially explosive atmospheres must only be placed in operation if it is follows from §6 of the explosion protection document that it can be used safely in potentially explosive atmospheres. In addition, the explosion safety of workplaces in potentially explosive atmospheres must be checked before they are used the first time by a qualified person who has special knowledge in the area of explosion protection.

If it is required in accordance with the risk evaluation, specific measures must be taken in the event of power failure, deviation from proper operation, devices and protection systems running in automatic mode and activation of emergency shut-off mechanisms so that these states do not result in additional risk.

Part B of appendix 4 specifies the criteria for selecting devices and protection systems. According to it, devices and protection systems must be selected in potentially explosive atmospheres to match categories in accordance with Directive 94/9/EC (ATEX 95):

- in Zone 0 or Zone 20: Devices of category 1
- in Zone 1 or Zone 21: Devices of category 1 or category 2
- in Zone 2 or Zone 22: Devices of category 1, category 2 or category 3.

The outcome that "Because, on the basis of the results of the risk assessment, no changes are envisaged in the explosion protection document, in hazardous areas devices and protection systems are to be selected in accordance with the categories in the Directive 94/9/EG" it appears appropriate to the author of the manual to insert as the opening clause, electrical apparatus, which have no category designation, e. g. all electrical apparatus for use in areas with combustible dust, which are approved in accordance with the new IEC standards. This is dealt with in detail in section 7 of the manual.

§ 6 – Explosion protection document

In accordance with the first paragraph of this section, the employer must create an explosion protection document regardless of the number of employees and must keep it up to date.

It must follow from the explosion protection document in accordance with Paragraph 2 that the explosion dangers have been determined and evaluated, that appropriate precautions have been taken to ensure explosion protection, which areas have been divided into zones and which areas the minimum requirements of appendix 4 apply to.

In accordance with Paragraph 3, the explosion protection document must be created before work is started. It must be revised if the work equipment or work process are modified, expanded or reworked.

Furthermore, the employer must meet his coordination obligations for performing all measures related to the safety and health protection of employees and must specify the goal, measures and conditions for carrying out this coordination in the explosion protection document.

The intent of this requirement described in Paragraph 4 is that if working material is provided to employees by different employers at one and the same workplace and is used there by them, t must be specified which employer is responsible for coordinating the necessary explosion protection measures.

When creating the explosion protection document, already existing danger evaluations, documents or other similar reports can be used in accordance with Paragraph 5.

This also clarifies that under some circumstances it is not necessary to create a new or independent explosion protection document if the required materials represent partial documentation of a more comprehensive documentation package already in existence.

A further consequence of Paragraph 5, however, is that to create an explosion protection document, it may be sufficient to combine existing partial documentation elements. If this is done, special attention must be paid to ensuring the completeness of all required documentation materials.

Under 2.4, the requirements for the explosion protection document are described in more detail. This section also contains a same sample breakdown of content from which the required content of an explosion protection document can be derived.

§ 7 – Requirements for the properties of work equipment

Paragraphs 1 and 2 describe in general the requirements of the work equipment that the employer provides to employees.

Paragraphs 3 and 4 apply to work equipment for use in potentially explosive atmospheres. According to these sections, work equipment that is provided to employees for the first time after June 30, 2003 must meet the requirements of appendix 4, sections A and B.

They must be identified with the required device category (1, 2 or 3) for use in the respective zone and must accordingly have been subjected to the conformity evaluation process described in ATEX 95 unless something to the contrary is outlined in the explosion protection document on the basis of a hazard analysis.

Since this discussion concerns only providing the material and not actually using it, however, first-time use of equipment that does not conform to the requirements of ATEX 95 is permissible after July 1, 2003 if the equipment in question had already been provided before that date.

Section 4 specifies that all work equipment already in operation before June 30, 2003 in potentially explosive atmospheres must meet the minimum requirements of appendix 4, section A. However, this applies only if no other EC directive is in force either entirely or in part before this date.

Paragraph 5 requires the employer to take all necessary measures so that work equipment will meet the requirements of the previous paragraphs throughout the entire time it is used.

§ 8 – Other protective measures

If the work equipment involves special dangers, the requirement is made here that the employer must take care that only employees entrusted to do so use work equipment that involves special dangers.

§ 9 – Training and instructions

Paragraphs 1 and 2 of § 9 explain concrete requirements of the employee to provide instructions to employees in accordance with the Work Protection Law. Since this law applies to all workplaces and there is no other more extensive requirement for potentially explosive atmospheres, it will not be discussed in any greater detail here.

There are additional requirements in potentially explosive atmospheres in reference to instructing and training employees that must be described in the explosion protection (see also § 5 in combination with appendix 4).

§ 10 – Check of work equipment

The employer must ensure that work equipment is tested before the first time it is placed in service (Paragraph 1), that it undergoes recurring tests as part of the intervals determined according to § 3 or based on extraordinary events that threaten safety (Paragraph 2) and that it is tested by a qualified person after repair jobs that could have a negative impact on the safety of the work equipment (Paragraph 3).

In accordance with Paragraph 4, both the test and the test result must meet the requirements of the danger evaluation in accordance with § 3.

Regarding tests on systems requiring inspection, §§ 14 through 20 must also be observed.

§ 11 – Recording results

The results of tests must be documented according to § 10. They must be kept on file to be made available to the responsible authorities upon request at any time and must be kept at least until the next test.

2.2.3 Section 3: Special requirements for systems requiring inspection (§§ 12 through 23)

§ – 12 Operation

In accordance with Paragraph 1, systems requiring inspection, which includes among other systems in potentially explosive atmospheres must be assembled, installed and operated according to the latest state of the art. The technical rules determined by the Committee for Industrial Safety and published by the German Federal Ministry for Work and Social Order must be observed.

Paragraph 2 makes the requirement that a system requiring inspection must only be placed in operation if it meets the requirements of EC law or – if there are no such requirements – that it represents the latest state of the art.

While Paragraphs 3 and 5 require in general that systems requiring inspection be kept in proper working order and are only operated if no defects are apparent that could endanger employees or third parties, Paragraph 4 contains a special requirement for elevator systems that will not be noted here.

§ 13 – Conditional approval

This paragraph regulates the need for approval for certain systems requiring inspection, such as steam boiler systems, filling systems for compressed gases, storage systems and storage, filling and emptying stations for readily and highly ignitable liquids and aircraft field fuel tank systems for flammable liquids that require approval.

A system in a potentially explosive atmosphere does not require any approval as long as its need for monitoring is not derived from one of the features described above.

§ 14 – Check before commissioning

In accordance with Paragraphs 1 and 2, a system requiring inspection must only be placed in operation the first time after a significant modification or after a modification that affects the operation or design of the system if it has been checked by an approved inspection agency.

Paragraph 3 describes the exceptions for which no test by an approved monitoring centre is required. For the area of explosion protection, this includes devices and protection systems as well as safety, monitoring and control equipment as defined by ATEX 95 plus systems consisting entirely of devices and protection systems as well as safety, monitoring and control equipment as defined by ATEX 95. Accordingly, this equipment and these systems for use in hazardous areas must only be tested by a qualified person.

Paragraph 6 of § 14 is still of interest for the area of explosion protection. This paragraph describes the checks required for a system (which may also be a device as defined by ATEX 95 in accordance with § 2) after a part on which explosion protection depends has been repaired.

The checks after repair must be performed by an approved inspection agency, a qualified person of a company that repairs such systems who is recognised as such by the authorities or the manufacturer of the system.

The requirements for qualified persons are described in the Technical Rules for Industrial Safety TRBS 1203.The requirements are also summarised here under § 2 "Definitions of terms".

§ 15 – Recurring checks

In accordance with Paragraph 1, systems requiring inspection must be checked at specific recurring intervals by an approved inspection agency. The exceptions that can be used in checks of systems in potentially explosive atmospheres before first being placed in service (§ 14 Paragraph 3), also apply to recurring checks.

The operator of a system requiring inspection must determine the check intervals based on a safety-related evaluation (see also § 3). The maximum interval of 3 years must not be exceeded for hazardous areas (Paragraph 15).

If the hazardous area is also at the same time a storage facility, tank, filling or emptying centre in accordance with §1 Paragraph 2, in that case alone, there is a maximum test period of 5 years. Tests on these systems must only be performed by an authorised monitoring centre. Tests performed by qualified persons are not sufficient for these systems (paragraph 16).

If recurring tests need to be performed by an authorised monitoring centre, the testing centre must evaluate the testing period determined by the operator. If the approved inspection agency determines a shorter check interval than the one specified by the operator, the approved inspection agency must notify the responsible authorities of the different check intervals. In this case, the responsible authorities will determine the binding check intervals and times, in some circumstances taking into consideration an evaluation of another approved inspection agency at the expense of the operator (Paragraph 4).

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In accordance with Paragraph 2, the recurring checks consist of a technical check that is performed on the system itself using check rules as well as an order check.

The remaining paragraphs of § 15 describe the basic requirements for recurring checks of other systems requiring inspection. Some specifications are also made concerning the days from which the periods for recurring checks start to run (Paragraphs 18 through 20) as well as the possibility of check deadlines being extended or moved up by authorities (paragraph 17).

Consequently the following is established:

The operator of a plant for which monitoring is required can appoint a competent person for the examination of explosion protection in accordance with § 14 paragraphs 1 to 3 and § 15 BetrSichV, who is permitted to undertake the examination/testing of the plant before commissioning and the recurring testing. This competent person is appointed by the employer to undertake the testing of the operating means on the basis of the risk assessment in accordance with § 3 of BetrSichV.

On inspection of the test steps listed in detail in the standards EN 60079-17 and EN 61241-17 in the context of a test prior to commissioning, careful consideration is given as to whether a particular task should be carried out by a competent person from the group of employees concerned in accordance with BetrSichV § 14 paragraph 3 or a competent person in accordance with § 14 paragraph 1 (employee of an approved monitoring centre). In the case of recurring tests the situation is decidedly different.

§ 16 – Ordering an extraordinary check

If an incident causing damage has occurred or there is reason to believe that a system requiring inspection has safety-related defects, the responsible authorities may order an extraordinary check. The operator must perform an extraordinary check ordered in this manner immediately.

§ 17 – Check of special pressure vessels

This paragraph does not contain any information relevant to explosion protection.

§ 18 – Signs of accidents or damage

Operators of a system requiring inspection must immediately report to the responsible authorities any accident in which a person is killed or injured or any damage resulting from a failure of safety-related mechanisms (Paragraph 1).

The authorities may then require that the displayed result be evaluated by an approved inspection agency in terms of safety (Paragraph 2).

§ 19 – Test certificates

A test certificate must be created for each test of a system requiring inspection. The test results of a test performed by a qualified person must be recorded (Paragraph 1).

The test certificates and recorded results must be kept on file (Paragraph 2).

§ 20 – Signs of defects

If the approved inspection agency has discovered defects during the test that endanger employees or third parties, the responsible authorities must be notified immediately.

§ 21 – Approved inspection agencies

This paragraph describes requirements for approved inspection agencies.

Of interest to the area of explosion protection is the requirement that an approved inspection agency able to perform tests on systems in potentially explosive atmospheres must at the same time be capable of performing tests on storage systems, filling and emptying stations as well as service stations and aircraft field fuel storage systems for ignitable, readily ignitable and highly ignitable liquids.

§§ 22 and 23

These sections deal with two topics: a definition of the Federal supervisory authorities for systems requiring inspection (§ 22) and a description of the requirements for use of portable pressure vessels within a given operation (§ 23).

2.2.4 Section 4: General requirements and final requirements (§§ 24 through 27)

§ 24 – Committee for Industrial Safety

A Committee for Industrial Safety has been formed by the German Federal Ministry for Work and Social Order. This committee will determine the rules by which these requirements made in the Industrial Safety Regulation may be met.

Representatives of public and private employers, state authorities, trade unions, carriers of accident insurance and approved centres will be represented on the Committee for Industrial Safety.

The rules and required knowledge determined by the Committee for Industrial Safety may be published by the German Federal Ministry for Work and Social Order in the Federal Work Gazette. In observing these rules and required knowledge, it may be assumed that the requirements made in the Industrial Safety Regulation are observed.

In addition to the already mentioned documents:

- TRBS 1201 "Testing of operating means and plant requiring monitoring",
- TRBS 1203 "Competent persons",
- TRBS 2152 "Dangerous explosive atmospheres",

there are other TRBS, which were published in the first half of 2006 and relate to the overall theme of explosion protection.

- TRBS 1001 "Structure and application of the technical rules for operating safety" contains general information on the technical rules.
- TRBS 1002 "Definitions" defines, among other things, the "State of the art", as referred to in ATEX 95.

The "State of the art" is the state of the development of progressive processes, devices and/or methods of operation, which have become established in the practical application of measures to ensure the safety and the improvement of the health and safety of employees involved in the preparation and use of working substances and in the protection of employees and third parties from the risks involved in the operation of plant requiring monitoring. In determining the state of the art, those processes, devices and methods of operating have to be considered, which have been successfully evaluated in practice. The state of the art reflects the state of the respective technical development".

TRBS 1111 "Risk assessment and safety evaluation" describes the procedure for the determination and evaluation of risks and the derivation of the necessary measures for the preparation and use of working substances and the operation of plant subject to monitoring [Federal Institute for Safety at Work and Industrial Medicine].

§§ 25 and 26

§§ 25 and 26 describe actions contrary to regulations or even a punishable offense in reference to the goal of the Industrial Safety Regulation.

No further details will be discussed in this context.

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§ 27 – Transitional requirements

In accordance with the first paragraph of this section, the operator of a system in a potentially explosive atmosphere must fulfil the obligation to create an explosion protection document no later than **December 31, 2005** if the system was placed in operation before October 3, 2002.

However, this also means that there must be an explosion protection document for every system in a potentially explosive atmosphere that was placed in operation for the first time after October 3, 2002.

Paragraph 2 makes it lawful to continue operating systems requiring monitoring that were in operation before January 1, 2005. However, this only applies if they had been authorised to operate before that date.

In accordance with Paragraph 3, requirements for properties required of systems placed in operation for the first time before January 1, 2003 do not need to be adjusted to fit the new requirements. Responsible authorities may, however require such an adjustment if there are special dangers to fear.

The operating requirements contained in the regulation must be adopted no later than December 31, 2007. The tests described here and determination of test intervals are the most important issues to consider.

"Old" systems are not required to report the test interval to the authorities or to have the test period verified by an authorised monitoring centre.

Paragraph 6 of § 27 deserves special attention. Through it, the **technical rules** previously determined based on a statutory regulation according to § 11 of the Device Safety Law **will continue in force** until a revision is released by the Committee for Industrial Safety.

For example, this means for potentially explosive atmospheres that have until now fallen under the "Regulation concerning flammable liquids" (referred to as the VbF) that the **"Technical rules concerning flammable liquids – TRbF"** will continue to be valid. Examples that may be cited here include TRbF 20 "Storage" or TRbF 40 "Service stations".

2.3 Modification of the Hazardous Substance Regulation

The Hazardous Substance Ordinance is modified by article 6 of the "Regulation for Legal Simplification in the Area of Safety and Health Protection in Providing Work Equipment and its use in Work, Safety in Operating Systems requiring inspection and the Organisation of Work Protection" dated September 27, 2002.

Among other changes, appendix V "Special requirements for certain hazardous substances and activities" was expanded. section No. 8 "Fire and explosion dangers" was added.

The newly added section of appendix V of the Hazardous Substance Regulation applies to the protection of employees and others from the danger of fire and explosions when working with hazardous substances.

As in the Industrial Safety Regulation, the employer is also required in this case to perform and document an evaluation of danger before beginning work. If the formation of a dangerous potentially explosive atmosphere cannot be excluded based on this danger evaluation, additional measures are necessary depending on the requirements of the Industrial Safety Regulation.

The following order of priority must be observed when applying protective measures against fire and explosion dangers:

1. Preventing the formation of dangerous potentially explosive mixtures **(primary explosion protection)**
2. Preventing the ignition of dangerous potentially explosive mixtures **(secondary explosion protection)** and
3. Limiting the damaging effects of an explosion to a negligible level **(tertiary explosion protection)**.

In addition to some requirements for limits of quantities and protection against unintentionally releasing harmful substances, requirements for except and rescue routes, warning and prohibition signs as well as the obligation for coordination if multiple employers are active at the same workplace are described in this appendix to the Hazardous Substance Regulation in reference to the work process.

In addition, and beyond the requirements of the Industrial Safety Regulation, measures must be taken to eliminate hazardous substances that could potentially be released by a fire or explosion if this is possible according to the state of the technology.

Furthermore, work areas with the danger of fire and explosion must be provided with adequate automatic or non-automatic fire extinguishing systems. Transfer of fires and the effects of fires and explosions to neighbouring areas must be prevented. It must also be possible to reach these work areas quickly and without hindrance with fire extinguishing tools and devices to fight the fire.

Additional requirements are placed on storage of hazardous substances that could result in the danger of a fire or explosion. The storage locations must be suitable for the materials being stored. Mixed storage is only permitted if doing so does not result in any danger. Furthermore, storage facilities for highly ignitable, readily ignitable or ignitable liquids must be provided regardless of the danger of explosion with the following warning sign:

Figure 2.2 Identification of areas with danger of fire in accordance with the Hazardous Substance Regulation

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2.4 The explosion protection document

2.4.1 Preliminary remarks

In accordance with § 6 of the Industrial Safety Regulation, the employer must create an explosion protection document regardless of the number of employees and must keep it up to date.

This document must be on file before work is started for systems that were placed in operation for the first time after October 3, 2002.

For systems that were already in operation before October 3, 2002, the explosion protection document must be created no later than December 31, 2005.

The following section describes both the general requirements as well as a rough procedure to following in creating the explosion protection document. This explanation is intended to illustrate the basic layout of an explosion protection document by means of a sample breakdown of contents.

2.4.2 General requirements

Explosion protection documents and the additions made to them are not bound to any format. Minimum requirements derived from the Industrial Safety Regulation are simply stated in terms of the content.

According to this, the explosion protection document must clearly show that the dangers of explosion have been determined and evaluated based on an evaluation of dangers and that reasonable precautions are being taken to achieve the goals of explosion protection. Furthermore, in addition to categorisation into zones, the determination of areas to be included in explosion protection measures (for example escape and rescue routes for workplaces outside of the potentially explosive atmospheres) must be an integral part of the explosion protection document.

In general, the layout of the explosion protection document should be formal and structured. Responsibilities and areas of oversight must be clearly regulated in the explosion protection document. The organisational structure of the operation must be illustrated for this purpose and all responsible persons should be involved in creating the explosion protection document.

Furthermore, work processes and tools as well as the goal and scope of protective measures must be documented in detail.

All malfunctions in work processes, machines and tools must be taken into consideration.

The risks must be specified and protective measures must be described. To do this, the explosion risks must above all be determined, and the areas in which it is not possible to reliably prevent the occurrence of a dangerous potentially explosive atmosphere must be classified into zones according to the duration and probability of the occurrence of a dangerous potentially explosive atmosphere.

If changes or modifications are made to the system, the work process or the workplace, the validity of the explosion protection document must be verified and if appropriate the document must be adapted.

2.4.3 Procedure for creating the explosion protection document

A substance list must be created to determine whether there are dangers of explosion for a system. This list of substances must contain the safety-related characteristic values relevant to the evaluation (for example the flash point in the case of flammable liquids).

This must be used to create a description of the process for the system. A description of the individual work steps and the organisation of the work process must also be included.

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Based on this compilation and taking into consideration additional system parameters relevant for explosion protection, which must also be described, potentially explosive areas must be categorised into zones, based on consultation of the applicable standards. When categorising areas into zones, the DIN EN 60079-10 (VDE 0165, part 101), the DIN EN 50281-3 (VDE 0165 part 102) and other bodies of technical rules on the national level may be consulted. This includes, among others TRbF 20 for storage facilities, TRbF 40 for service stations, but also the explosion protection rules (BGR 104) in general.

In connection with determining zones, possible ignition source in accordance with EN 1127-1 and BGR 104 must be taken into consideration. If the occurrence of one of the ignition sources listed there is possible, that ignition source must be described and the protective measures that are taken must be specified.

In doing so, there must always be a detailed and documented evaluation of all work equipment that is used in the potentially explosive atmospheres. In addition to electrical equipment, non-electrical equipment and components must also be taken into consideration. If there is no manufacturer's certificate of conformity and marking in accordance with ATEX 95 for non-electrical equipment and components (this is required without exception if the equipment was placed in circulation after June 30, 2003), it must be determined based on a risk evaluation based on DIN EN 13463-1 whether these system parts can be safely operated in the respective zones.

Electrical devices must also comply with ATEX 95 if they were made available to employees for the first time after June 30, 2003. Since declarations of conformity (for Zones 0, 1 and 10) or manufacturer's declarations (for Zones 2 and 11) were already required before this date for electrical devices that were used in potentially explosive atmospheres, and they were required to be manufactured and operated in accordance with the requirements of the respective zones, it is possible to continue using them.

However, there could be difficulties with explosive dust atmospheres, since the devices used must be more thoroughly evaluated because of the new categorisation into zones (Zones 20, 21 and 22 instead of Zones 10 and 11).

Mutual effects between individual work equipment must also be described and evaluated in terms of a possible explosion hazard.

Special attention must be paid to dangers caused by electrostatic charges. The possible hazards and the corresponding protective measures must be described. BGR 132 ("Static Electricity" directives) must be consulted in considering these hazards and the necessary protective measures.

Based on the description of technical protective measures, all organisational measures for preventing explosion hazards must be described.

These organisational measures include both measures to prevent a potentially explosive atmosphere from occurring already during the work process (for example exercising special care in closing or moving containers; cleaning accumulations of dust) as well as measures intended to prevent ignition sources from occurring (for example wearing conducting footwear). Work instructions must be created for these measures, and the work instructions are then an integral part of the explosion protection document.

However, the organisational measures also include creating escape and rescue route plans and instructions to employees about protective measures that must be observed (as described above), about measures to be observed for certain jobs in potentially explosive atmospheres ("fire approval" as it is called) and measures to be introduced if alarms occur (for example a warning through a gas warning system or an acoustic warning for ventilation failure). In addition, employees working in potentially explosive atmospheres must be informed of escape and rescue possibilities and any materials required for escape.

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This explanation makes no pretense to completeness. The special dangers and different possibilities for protection from explosion must be described in detail for each system.

The explosion protection document must demonstrate that all dangers have been taken into consideration. In addition, the scope of both technical and organisational protective measures must be described according to the possible dangers. Observing these documented protective measures should ensure safe and reliable operation of the system.

Because of the numerous parameters that must be taken into consideration in creating an explosion protection document, an explosion protection document must always be created individually for a specific system. Transferring an explosion protection document to another comparable system always requires an evaluation to determine whether there may not actually be other conditions present that affect safety negatively under some circumstances.

2.4.4 Sample classification of an explosion protection document

The layout of an explosion protection document is illustrated in the example below. This example is based essentially on the example from section E 6 of BGR 104.

1. Specification of the type of operating process involved (for example system, storage, building)
2. Person responsible for operating area, date of creation and appendices
3. Brief description of specific features of the building and surrounding area (for example site map, building plans, setup plan, building or system ventilation)
4. Description of process – the essential process parameters for explosion protection (for example a brief description of the process involved, relevant activities (for example taking of sample), materials used, amount used/amount conveyed, processing state, pressure and temperature range)
5. Material data

   Significant safety-related rating data for evaluating explosion protection measures, for example from the safety data sheet or other collections such as CHEMSAFE, Nabert and Schön, BIA report, etc.

   Material data for flammable liquids/gases, for example:
   - Flash point of flammable liquids
   - Lower and upper explosion limit
   - Density compared to air
   - Ignition temperature (temperature class)
   - Explosion group
   - Limit concentration of oxygen
   - Vapour pressure of flammable liquids

   Substance data for flammable dusts, for example:
   - Granularity distribution (median value)
   - Lower explosion limit
   - Minimum ignition power
   - Maximum explosion pressure
   - C_{DE} value (dust explosion class)
   - Ignition temperature of dust that is stirred up
   - Ignition temperature of accumulated dust (smoulder temperature)
   - Limit concentration of oxygen
   - Specific electrical resistance of the flammable dust

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6. Evaluation of danger
   6.1 The probability and duration of the occurrence of a dangerous potentially explosive atmosphere. Can a potentially explosive atmosphere occur and is it dangerous based on local and operating conditions?
   6.2 The probability of the presence and activation of ignition sources and of their becoming effective, including electrostatic discharge
   6.3 Extent of anticipated effects of explosions
7. Protection concept
   7.1 Technical protective measures for preventing or limiting a dangerous potentially explosive atmosphere (for example ventilation, monitoring of concentration, inertisation)
   7.2 Classification into zones (nature, extent and documentation)
   7.3 Protective measures
   Preventing ignition source and design-based explosion protection (selection of equipment and protection systems)
   7.4 Organisational measures
   (instructions for employees, written instructions, work release
8. Evaluation of the extent of effects from explosions to be anticipated
9. Monitoring of the effectiveness of measures taken

2.5 Testing and maintenance of electrical systems in explosive atmospheres

2.5.1 General

Section 5 describes the installation of electrical systems in potentially explosive atmospheres. The requirements of DIN VDE 0100, part 610 always apply to the initial test of these systems as well as to other electrical systems.

Operation and maintenance of systems means preserving a proper condition to ensure safe and reliable operation of the system.

Special requirements must be placed on the qualifications of staff members to ensure that these tasks can be performed as carefully as possible according to the potential for danger of electrical systems in potentially explosive atmospheres. These staff members should have specialised knowledge and experience for evaluating electrical relationships and must be familiar with the basic requirements for hazardous areas such as a knowledge of different ignition protection classes, flash point, density ratio, etc.

When operating electrical systems, the following technical rules should be observed in general:

- The accident prevention requirement "Electrical systems and equipment" BGV A3
- DIN EN 50110-1 (VDE 0105, part 1) "Operation of electrical systems: General requirements"
- DIN EN 50110-2 (VDE 0105, part 2) "Operating electrical systems (national appendices)"
- DIN VDE 0105-100 (VDE 0105, part 100) "Operating electrical systems (national appendices)"

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The following must be observed in addition for electrical systems in potentially explosive atmospheres due to increased danger:

- DIN EN 60079-17 (VDE 0165, part 10) "Electrical apparatus for explosive gas atmospheres, part 1: Testing and maintenance of electrical systems in potentially explosive atmospheres (except for underground construction)"
- DIN EN 61241-17 (VDE 0165-10-2) Electrical apparatus for use in areas with combustible dust, part 17: Testing and maintenance of electrical systems in hazardous areas (with the exception of mining operations) (IEC 61241-17: 2005).

This standard also describes additional requirements for initial testing of electrical systems.

DIN VDE 0105, part 9 "Operating high-voltage systems; additional specifications for hazardous areas" has been withdrawn and is no longer valid as of February 1, 2001.

The following sections contain only brief sketches and summaries of the additional requirements for operating electrical systems in potentially explosive atmospheres.

A knowledge of the requirements of the standards listed here is indispensable for operators of electrical systems in potentially explosive atmospheres or for specialist staff members entrusted with working on these systems to ensure proper operation of these systems.

The following summary makes no claim to being complete and cannot replace reading of the technical rules.

2.5.2 Testing and maintenance of electrical systems in potentially explosive gas atmospheres

Standard DIN EN 60079-17 (VDE 0165, part 10-1) "Electrical apparatus for explosive gas atmospheres, part 17: Testing and maintaining electrical systems in potentially explosive atmospheres (except for mining construction)" is intended for operators of electrical systems in potentially explosive atmospheres.

In addition to requirements for sufficient documentation and adequate qualification of staff members, the standard also describes how to determine test intervals.

In general, after an initial test, recurring tests should be performed at intervals selected so that any defects that occur of the type that must be counted on can be detected in good time.

After the test interval is specified, however, random tests are required in the interim period to confirm or modify the time interval that was specified.

In addition to specifying the test dates, the depth of the test must also be specified. The test may be a visual inspection, a close-up test or a detail test. These terms are defined in the standard as follows:

Visual inspection: A test in which visible faults are determined without using devices to access internal parts or tools – for example to note missing screws.

Close-up check: A test in which, in addition to the aspects of the visual inspection, errors such as loose screws are noted that can only be detected by using devices to access internal parts, for example tools. Generally a housing needs to be opened for close-up tests or the power must be disconnected from the equipment.

Detail check: A test in which, in addition to the aspects of the close-up test errors such as loose connections are discovered that can only be found by opening the housing and/or using tools and testing devices if necessary.

Initial tests must always be conducted as detail tests. Recurring tests can be performed as close-up tests or visual inspections. A recurring visual or close-up test may result in a detail test being required in addition.

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When determining test intervals and the depth of recurring tests, the following factors must be considered:

- Nature of the equipment
- Manufacturer's information (if present)
- Factors affecting wear and tear (for example susceptibility to corrosion, effects of chemicals or solvents, accumulations of dust or dirt, ingress of water, increased ambient temperatures, etc.)
- Zone of installation location
- Results of previous tests
- Experience with comparable systems and equipment under similar operating conditions

The maximum test cycle must not exceed three years. This requirement is in conformity with the requirements of the Industrial Safety Regulation.

The statement that the test interval can also be longer than three years with the approval of experts cannot be reconciled with the Industrial Safety Regulation and therefore cannot be used.

Because of the special stresses on these devices, a close-up test must be performed for portable electrical equipment at least once every 12 months.

As for determining the test interval, when determining the depth of the test, random interim tests must confirm or modify the test depth that was selected.

Test intervals and test depths as well as the results of all tests must be documented and integrated into the explosion protection document. This will make it possible to track both test intervals and test depth.

DIN EN 60079-17 (VDE 0165, part 10-1) contains test plans in the form of tables that specify the special tests for different ignition protection classes required for visual inspections, close-up tests or detail tests ("d", "e", "n"; "i" and "p").

Additional requirements for test plans are described in section 5 of the standard. A few items from the test plans are discussed in concrete terms or further explained in this section and in section 4.10. Essentially, these sections deal with special features of different ignition protection classes.

In addition to requirements for the test of electrical devices, the content of DIN EN 60079-17 (VDE 0165, part 10-1) also describes points that must be observed in maintaining and repairing these systems.

When maintaining and repairing equipment, care must be taken that the effectiveness of the ignition protection method for the equipment remains intact.

If replacement parts are used, they must match the requirements of the safety documentation (for example the manufacturer's instruction manual).

It should be noted in this context that the Industrial Safety Regulation must be observed for certain repair tasks. If a part of a piece of equipment has been repaired and explosion protection depends on the part, the device in question must not be placed in operation again until after it has been tested by an approved inspection agency, a qualified person recognised by the responsible authorities or the manufacturer of the device.

Examples of repair jobs like this are:

- Replacing the winding in a motor of ignition protection class EEx e (original replacement parts must be used)
- Replacing terminal boxes in a motor of ignition protection class EEx e (original replacement parts must be used)
- Rewinding a motor of ignition protection class EEx e to another voltage if the new voltage level for the motor is already certified
- Replacing inner wiring of lights of ignition protection class EEx e
- Replacing pressure-sealed line lead-ins on devices of ignition protection class EEx d (original parts must be used)
- Replacing housing parts on equipment of ignition protection class EEx d (original replacement parts must be used)

The modification mentioned in the standard that cannot be performed without appropriate approval, is conducting, since the manufacturer's declaration of conformity is voided if modifications are made to equipment.

In these cases, the conformity process must be gone through again in accordance with Directive 94/9/EC (ATEX 95).

For example, the following modifications to explosion-protected electrical equipment would make it necessary to repeat the conformity evaluation process:

- Replacing pre-switching devices that are not noted in the test certificate on lights of ignition protection class EEx e
- Rewinding a motor of ignition protection class EEx e to another voltage if the new voltage level for the motor is not certified

DIN EN 60079-17 (VDE 0165, part 10-1) describes additional measures that are required if equipment must be disassembled entirely, for example because of repair jobs. Special precautions must be taken for exposed connection leads (closing, separating and isolating or disconnecting and grounding or removing for final disassembly).

In general, maintaining and repairing equipment must not have a negative effect on the safety of the system or equipment.

Additional points covered in the standard are:

- Considering ambient conditions. Special care must be taken that if nothing else is specified on the equipment, it can only be used in the temperature range from -20 °C to +40 °C. Furthermore, all damaging external influences (for example corrosion, UV radiation, water, dust, etc.) must be taken into consideration
- Avoiding electrostatic charges when cleaning equipment
- Observance of electrical isolation of equipment. The conditions are also specified here under which working on open equipment under voltage is permitted in potentially explosive atmospheres in addition to precautionary measure for working on intrinsically safe circuits (including in non-hazardous areas)
- Requirements for checking grounding and potential equalisation connections
- Making note of equipment with "special conditions" (identified by X)
- Special consideration when using portable equipment in reference to the correct ignition protection class or category corresponding to the zone, explosion group and temperature class.

New additions with the June 2004 edition of DIN EN 60079-17 (VDE 0165, part 10-1) are the sections "Regularly recurring tests" and "Continuous monitoring by specialised personnel".

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The new version now draws a clearer distinction between the initial test and recurring tests. The requirements for personnel entrusted with the recurring test are also more clearly described.

The recurring tests on electrical systems in potentially explosive atmospheres require in accordance with this draft that the staff members:

- Have specialised knowledge and understanding of categorising areas into zones and sufficient technical knowledge to understand the significance for the location in question;
- Have specialised knowledge and understanding of the theoretical and practical requirements for the electrical equipment that will be used in potentially explosive atmospheres, and
- Understand the requirements for visual inspection, close-up test and detail tests in reference to installed devices.

The new section, which regulates continuous monitoring by specialised staff, specifies the requirements for the staff members entrusted with continuous monitoring. Since the requirements for staff are very high and in addition this type of monitoring cannot replace the test required in accordance with the Industrial Safety Regulation, it will not be discussed in any further detail here.

The initial and recurring tests described in the standard can be seen as tests on electrical systems that must be conducted by a qualified person in accordance with the Industrial Safety Regulation.

2.5.3 Testing and maintenance of electrical systems in potentially explosive dust atmospheres

DIN EN 61241-17 (VDE 0165-10-2) Electrical apparatus for use in areas with combustible dust, part 17: Testing and maintenance of electrical systems in hazardous areas (with the exception of mining operations) (IEC 61241-17: 2005) has a structure analogous to that of the test standard for areas endangered by gas explosion. The definition of terms is identical.

In section 6 "Typical test plans" there are test plans in tabular format for installations in the ignition protection classes Ex tD, Ex iD and Ex pD.

2.5.4 Technical rules for operating safety TRBS 1201 Testing of operating means and plant requiring monitoring

A publication of the Federal Institute for Safety at Work and Industrial Medicine (May 2006) records that the committee for operating safety, at its 10th session on April 27 and 28, 2006, ratified a number of TRBS including TRBS 1201.

The core of TRBS 1201 "Testing of operating means and plant requiring monitoring" is the specification of the requisite testing. In TRBS 1201 statements are made with regard to establishing the nominal condition, the person with the responsibility for the testing and on the type and scope of tests and time scales. Aspects of the way in which testing should be carried out are also included.

There is also a "firming up" in TRBS 1201 with regard to explosion protection. In TRBS 1201, part 1 "The testing of plant in hazardous areas and the examination of work stations in hazardous areas" there is information on the determination of test requirements, the development of testing concepts and the execution of testing, with special focus on this area.

Author's note: Since both of these items have yet to be published, further details cannot be provided at the time of the revision of the manual.

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2.6 References

BetrSichV	"Regulation regarding Safety and Health Protection in Providing Work Equipment and its use in Work, Safety in Operating Systems requiring inspection and the Organisation of Industrial Work Protection" (Industrial Safety Regulation).
GefStoffV	Regulation for Protection from Hazardous Substances (in German: Gefahrstoffverordnung)
ExVO	Eleventh regulation on the Device Safety Law (regulation on placing devices and safety systems in circulation for hazardous areas – explosion protection regulation – 11th GSGV)
ATEX 137	Directive 1999/92/EC of the European Parliament and Council of December 16, 1999 regarding minimum requirements for improving health protection and safety of employees who may be endangered by a potentially explosive atmosphere.
ATEX 95	Directive 94/9/EC of the European Parliament and Council of March 23,1994 for harmonising statutory requirements of member nations for devices and protection systems intended for use in potentially explosive atmospheres
DIN EN 1127-1	Potentially explosive atmosphere – explosion protection, part 1: basic principles and methodology
TRBS 1203	Technical rules for industrial safety – qualified persons
BGR 104 (earlier ZH 1/10)	"Rules for Safety and Health Protection at Work" Explosion protection rules (EX-RL)
BGR 132 (earlier ZH 1/200)	Directives for preventing ignition hazards resulting from electrostatic charge – "Static Electricity" directive
DIN VDE 0100	Setting up high-voltage systems with nominal voltages up to 1000 V
DIN EN 60079-10 (VDE 0165, part 101)	Electrical equipment for explosive gas atmospheres, part 10: Classification of explosive gas atmospheres
DIN EN 60079-14 (VDE 0165, part 1)	Electrical equipment for explosive gas atmospheres part 14: Electrical systems in hazardous areas (except for underground construction)
DIN EN 60079-17 (VDE 0165, part 10-1)	Electrical equipment for explosive gas atmospheres part 17: Testing and maintaining electrical systems in potentially explosive atmospheres (except for underground construction)
DIN EN 50281-1-2 (VDE 0165, part 2)	Electrical equipment for use in areas with flammable dust Main section 1: Electrical equipment with protection through housing Part 2: Selection, set-up and maintenance
DIN IEC 61241-17 (VDE 0165, part 10-2)	Electrical equipment for use in areas with flammable dust, part 17: Testing and maintaining electrical systems in potentially explosive atmospheres (except for mining construction)
Electrical explosion protection in accordance with DIN VDE 0165	Lienenklaus/Wettingfeld "Electrical explosion protection in accordance with DIN VDE 0165"; VDE series 65, 2. revised edition 2001, VDE Published by VDE, Berlin and Offenbach

3 Basic physical and technical principles of explosion protection

3.1 Preliminary remarks

An explosion is defined as a sudden increase in volume accompanied by an explosive noise with destructive effects. It is caused by a chemical or physical reaction.

For an explosion caused by a mixture of flammable gases, mist, vapours or dust with air to occur, the following condition must all be satisfied at the same time and in the same place:

- There must be a mixture of air and gases, vapours, mist or dust in sufficient quantity to pose a hazard (i. e. within explosion limits).
- There must be an effective ignition source.

The conditions for an explosion (presence of fuel, oxygen and an ignition source) can be illustrated in concrete terms by means of the "explosion triangle":

Figure 3.1 The explosion triangle

The goal of **primary explosion protection** is to prevent a quantity of a potentially explosive mixture large enough to present a hazard from occurring.

If it is not possible to prevent the occurrence of a dangerous potentially explosive atmosphere, then **secondary explosion protection** must be used. Its protective goal is to prevent ignition sources.

If it is not possible for reasons related to the process to adequately prevent the occurrence of either a dangerous potentially explosive atmosphere or an effective ignition source, **tertiary (design-based) explosion protection** must be used. Tertiary explosion protection limits the effects of an explosion to a level that poses no danger.

The following section discusses how to evaluate the occurrence of dangerous potentially explosive atmospheres as well as the basic principles of the explosion protection measures referred to above.

3.2 Definition of terms

Flammable substances are substances that enter into an exothermic reaction with air in the form of gases, vapours, liquids, solids or mixtures of these. This includes all substances that are categorised as flammable, readily flammable or highly flammable according to the Hazardous Substances Ordinance.

Potentially explosive atmosphere a mixture of air and flammable gases, vapours, mist or dust under atmospheric conditions in which the combustion process is transferred to the entire unburned mixture after the ignition has occurred.

Note

Atmospheric conditions include overall pressures of from 0.8 bar to 1.1 bar and mixture temperatures of from -20 °C to +60 °C.

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Explosion limits The lower explosion limit (LEL) and upper explosion limit (UEL) are defined as the lower and upper limiting values of the concentration of a flammable substance (gas, vapour, mist or dust) with air in which a flame independent of the ignition source is no longer able to propagate by itself after the ignition.

Flash point The lowest temperature at which a liquid gives off flammable gas or flammable vapour under previously described experimental conditions in sufficient quantity for a flame to occur on contact with an effective ignition source.

Dangerous potentially explosive atmosphere A dangerous potentially explosive atmosphere is a potentially explosive atmosphere in sufficient quantity to represent a danger. A quantity of a mixture is considered dangerous if igniting it results in damage.

Limit concentration of oxygen The maximum concentration of oxygen in a mixture of a flammable substance with air and an inert gas in which an explosion does not occur, as determined under specified experimental conditions.

Low speed detonation A low speed detonation is the transfer of a combustion process to an explosion. The capacity of the flame to propagate can vary from a few cm/s to a few m/s. Explosion pressures that are generated are relatively minor.

Explosion An explosion is a sudden oxidation or reduction reaction with an increase in temperature, pressure or both simultaneously (definition according to EN 1127-1).

The capacity of the flame to propagate can vary from a few m/s to many hundreds of m/s. The explosion pressure may reach 10 bar for gases and vapours (up to 14 bars for dust).

Detonation An explosion that propagates faster than the speed of sound (km/s). The propagation speed of the flame may be as high as 3 km/s and pressures up to 20 bar may occur.

3.3 Evaluation of the risk of explosion

An evaluation to determine whether there is a risk of explosion, i. e. whether the danger of a potentially explosive atmosphere occurring must be taken into account. It can only ever refer to one particular case.

To be able to properly estimate whether there is a risk of an explosion, specialists from different professional disciplines must generally work together. It may be necessary for a chemist, process industry specialist or mechanical engineer to work together with a specialist in explosion protection to evaluate all possible dangers.

In addition to the nominal ratings of the materials in use, parameters related to the process involved are especially important in the evaluation. For example, the risk of explosion may be caused both by evaporation of a puddle of liquid or when a liquid is sprayed under high pressure.

It is also important in evaluating the risk of an explosion to know whether atmospheric conditions are present. The range of concentration between the explosion limits generally increases as the pressure and temperature of the mixture increase.

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The relationships between explosion limits, explosion points, and flash point is illustrated by the graph representing the vapour pressure of ethyl alcohol below.

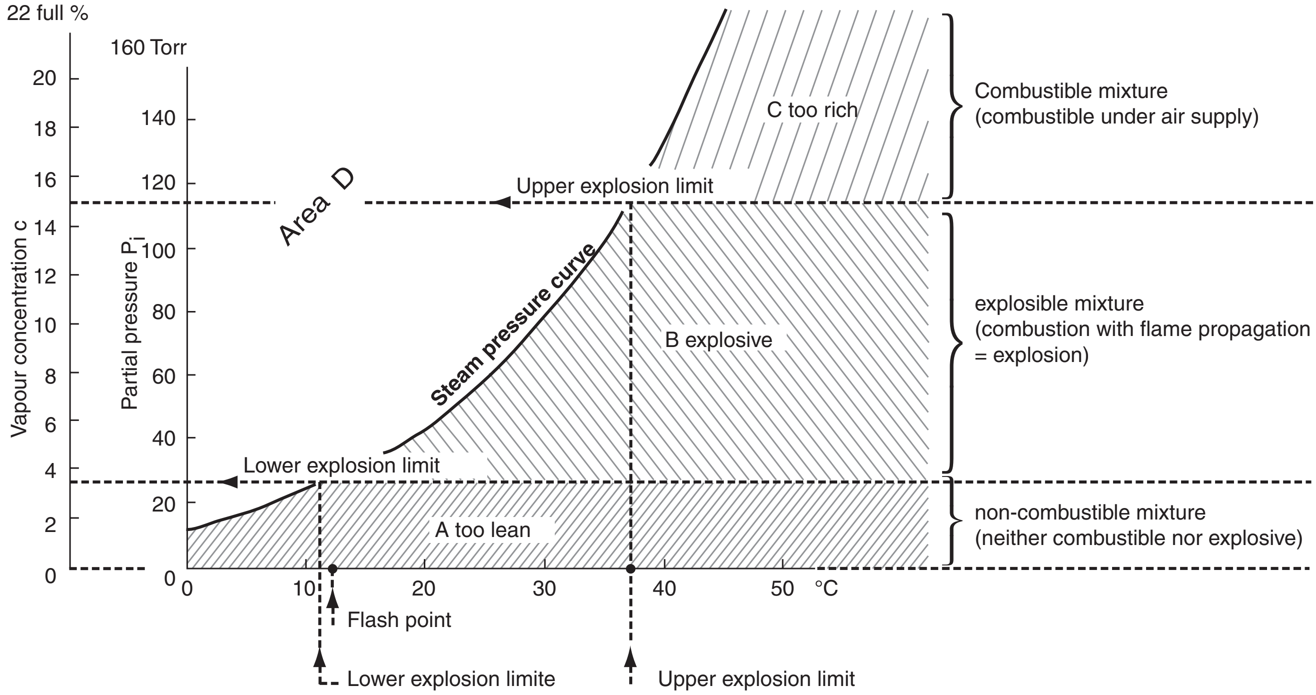

Figure 3.2 Graph representing the vapour pressure of ethyl alcohol

The atmosphere is capable of exploding within the explosion limits (Area B of the image). In Area A of the illustration (below the LEL), the mixture is no longer capable of ignition, since it is too "lean". The mixture is also not flammable in this area, although it does support a fire.

The mixture is also not capable of ignition in Area C, since it is too "rich" there, i. e. the oxygen content is too low for an explosion. If air is admitted, of course, this mixture becomes flammable.

In the area above the vapour pressure curve (Area D), mixtures can only exist for a limited amount of time under atmospheric conditions, while in the area under the curve, on the other hand, mixtures are not yet saturated.

The flash point is generally just a few degrees Kelvin above the lower explosion point. This safety-related nominal rating of substances is generally used to evaluate the risk of explosion and to classify substances as highly ignitable (flash point < 0 °C), readily ignitable (flash point between 0 °C and +21 °C) or ignitable (flash point between +21 °C and +55 °C).

Evaluating types of dust is more difficult, since the concentration can vary significantly as accumulated dust is stirred up or as floating dust is deposited.

A mixture that was previously too "lean" can be made potentially explosive as dust is stirred up, while a mixture that was previously too "rich" can be made potentially explosive as dust is deposited. Because of this, the danger of explosion is always a possibility when flammable dust is present. In evaluating whether the danger of explosion is present, after the materials in use have been analysed, the evaluation must then determine whether the potentially explosive atmosphere that might occur could be dangerous.

The explosion protection rules of BG Chemie (EX-RL, BGR 104) specify that even a quantity of 10 litres in an enclosed area must be considered potentially dangerous. In places with a volume of less than 100 m^3 hat, even quantities smaller than 10 litres may be dangerous.

The rule of thumb here is that a quantity of 1/10000 the volume of the enclosed space in question is considered potentially dangerous. For an enclosed space of 60 m^3, 6 litres of potentially explosive atmosphere would thus be potentially dangerous.

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However, this does not mean that the entire space must necessarily be considered a potentially explosive atmosphere. The hazardous area is only the partial area in which the potentially explosive atmosphere can occur.

The following sample calculation is intended to clarify how much volume of a potentially explosive atmosphere can result even from a small quantity of flammable liquid (in this case1 litre of petrol).

Intrinsic safety ID numbers for petrol:

- Explosion limits: 0.6 ... 8 Vol. %
- Flash point: < -20 °C
- Density: 0.7 g/cm³
- Molar weight: 80 g

The molar volume is a physical constant with: 1 mole = 22.4 liters of gas

1 litre of petrol with a weight of 700 g and a molar weight of 80 g yields 8.75 mole.

Since a mole is 22.4 litres of gas, 8.75 moles is exactly 196 litres. Thus, 1 litre of liquid petrol yields 196 litres of petrol vapour (100 %).

Considering the lower (0.6 %) and upper (8 %) explosion limit of petrol, the result is a potentially explosive atmosphere with a volume between (196 l/0.6% x 100%=) 32.7 m³ and (196 l/8% x 100% =) 2.45 m³.

If there is an evenly distributed layer of dust less than 1 mm in thickness, that is sufficient in accordance with the explosion protection rules of BG Chemie to fill a room of average height with a potentially explosive mixture of dust and air if it is stirred up.

The following illustration shows a few examples of potentially explosive atmospheres coming into existence.

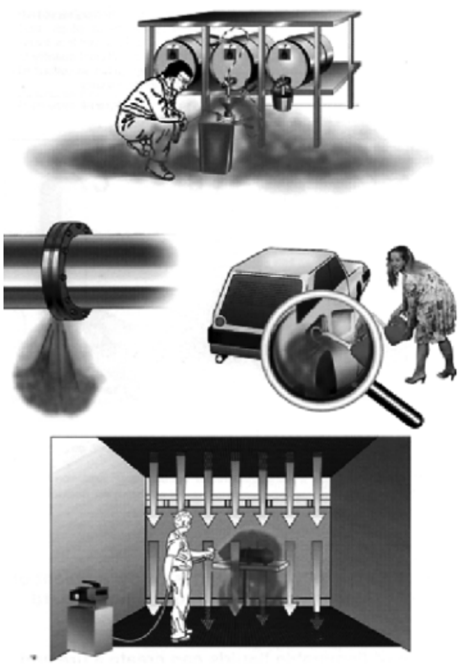

Figure 3.3 Examples of a potentially explosive atmosphere coming into existence
Source: Non-binding introductory manual for well-tried and tested processes relating to executing Directive 1999/92/EC

The following table contains a list of examples for explosion risks in various areas:

	Sector	Example of danger of explosion
	Chemicals industry	In the chemicals industry, flammable gases, liquids and solids are converted and processed in numerous processes. Potentially explosive mixtures may be generated during these processes.
	Landfills	Potentially explosive landfill gases may be generated in landfills. To prevent them from being able to offgas without any control and possibly being ignited, extensive technical measures are required.
	Power producing companies	Coal broken into pieces, which is not itself potentially explosive, may be processed into potentially explosive coal dust during the processing steps of conveying, grinding and drying.
	Waste management companies	Fermentation gases generated while processing waste water in settling facilities can form potentially explosive gas/air mixtures.
	Gas supply companies	Natural gas escaping due to leaks or similar processes can result in the formation of potentially explosive gas/air mixtures.
	Paint shops	The overspray that is generated while painting surfaces with spray guns in spray rooms is capable of causing a dust explosion.
	Agriculture	Systems for extracting biogas are operated in some agricultural facilities. If biogas is generated, for example due to leaks, this can lead to potentially explosive biogas/air mixtures.
	Metal processing operations	If shaped parts are manufactured from metal, potentially explosive metal dust may be generated while surfaces are being processed (sanding). This is especially true for light metals. This metallic dust may result in a risk of explosion in separators.
	Food and feed industry	Potentially explosive dust may be generated when transporting or storing wheat grain. If the dust is suctioned off and separated in filters, a potentially explosive atmosphere may occur in the filter.
	Pharmaceutical industry	Alcohols are frequently used as solvents in pharmaceutical production. In addition, potentially explosive dust may occur in effective and secondary agents, for example milk sugar.
	Refining	The hydrocarbons that are processed during refining are all flammable and, depending on the flash point, are already capable of causing potentially explosive atmospheres at the ambient temperature. The environment of equipment used to process natural gas is generally regarded as a potentially explosive atmosphere.
	Recycling operations	For example, when garbage is being prepared for recycling, risk of explosion can be caused by cans or other containers that have not been completely emptied of flammable gases and/or liquids or by dust from paper or synthetic materials.

Table 3.1 Examples for explosion risks in various areas

Source: Non-binding introductory manual for well-tried and tested processes relating to executing Directive 1999/92/EC

3.4 Avoiding a potentially explosive atmosphere – primary explosion protection

Once an initial evaluation as described in 3.3 has determined that the possibility of a dangerous potentially explosive atmosphere forming cannot be excluded, explosion protection measures are required. In accordance with article 3 of Directive 1999/92/EC (ATEX 137) and appendix V, No. of the Hazardous Substance Ordinance precedence should be given to measures for preventing dangerous potentially explosive atmospheres (primary explosion protection).

3.4.1 Replacement of flammable substances

The formation of a dangerous potentially explosive atmosphere can be prevented by replacing materials that are able to form a potentially explosive atmosphere with materials that cannot form a potentially explosive atmosphere. Examples of this are replacing flammable solvents or cleaning agents with aqueous solutions replacing flammable filling materials in the form of powders with non-flammable filling materials.

If the intent is to prevent a dangerous potentially explosive atmosphere from occurring with dust by using dust with coarser granularity, care must be taken that further processing does not result in finer granularity, for example due to abrasion. If this is so, additional explosion protection measures may be necessary.

3.4.2 Concentration limiting

Since gases and dust are only capable of exploding in a mixture of air within their explosion limits, it is possible to prevent the formation of a dangerous potentially explosive atmosphere by maintaining specific operating and ambient conditions. This can be achieved in the case of flammable liquids, for example, by always keeping the temperature on the surface of the liquid sufficiently far below the flash point. An interval of 5 K is considered sufficient for pure solvents, while a safety interval of 15 K is required for solvent mixtures.

It is much more difficult for dusts to achieve formation of a dangerous potentially explosive atmosphere through concentration limiting. Since it is always necessary to deal with the possibility of dust accumulations being stirred up and settling onto surfaces again, it is difficult to keep the concentration of dust in the air outside of the explosion limits.

The measures for limiting must be monitored. An example that could be mentioned here is temperature monitoring if the intent is to prevent the formation of a dangerous potentially explosive atmosphere by keeping the processing temperature sufficiently lower than the flash point.

A monitoring mechanism of this type must cause an alarm, automatic protective measures or automatic emergency functions to be triggered.

3.4.3 Inertisation

During inertisation, the formation of a dangerous potentially explosive atmosphere is prevented by diluting atmospheric oxygen within systems or the fuel by adding inert materials. Gaseous inert substances include non-reactive substances such as nitrogen, carbon dioxide or the inert gases.

For this protective measure, it is essential to know the maximum concentration of oxygen at which an explosion will not occur. This maximum concentration of oxygen, which is determined experimentally, is referred to as the limit concentration of oxygen. The highest permissible concentration of oxygen is thus derived from the limit concentration of oxygen minus a safety interval.

For this primarily explosion protection measure as well, the concentration of oxygen or the concentration of the inert gas must be monitored. When a specified alarm threshold is reached, protective measures must be performed or emergency functions must be triggered. This can be done manually or automatically depending on the requirements of the case in question.

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3.4.4 Preventing or limiting the formation of a potentially explosive atmosphere in the vicinity of systems

The occurrence of a dangerous potentially explosive atmosphere outside of equipment such as pipe lines with their connection points, pumps, measuring devices, etc. can be prevented by ensuring that this equipment is designed to be permanently sealed. The requirements for permanent technical sealing of equipment are described in the explosion protection rules BGR 104 in section E 1.3.2.1. In addition to purely design-based measures, technical measures associated with organisational measures can also ensure permanent technical sealing of apparatus.

If it is not possible to reliably prevent flammable substances from being released, then the formation of a dangerous potentially explosive atmosphere can be prevented or restricted through ventilation measures. The following points must be observed when designing ventilation:

- The maximum source current for gases and vapours that will be present as well as the location of the source and conditions for its expansion (for example with the density ratio compared to air) must be known when planning the dimensions of the ventilation system.
- In the case of dust, generally only object suction, which suctions off dust directly from the source from which it originates can ensure effective protection, since this also prevents accumulations of dust from forming.
- If ventilation-related mechanisms are sufficiently strong and can be reliably designed, the result may be that there is no need to specify any hazardous areas. However, they often result in a reduction of zones (for example Zone 1 becomes Zone 2) or in a modest extension of zones.
- The effectiveness of ventilation-related measures and associated monitoring devices must be demonstrated initially and then at recurring intervals by an authorised person.

Specific requirements for the design of the ventilation system and required monitoring equipment can be found in the explosion protection rules in section 1.3.4.

3.4.5 Monitoring the concentration in the vicinity of systems

Gas warning devices can be used to monitor concentration in the vicinity of systems. However, this must involve sufficient knowledge of the substances that are expected to be present and the location of their sources, their maximum source strengths as well as conditions determining their spread.

Gas warning devices must be suitable for usage conditions in respect to response time, response value and source sensitivity. The device must work reliably, i. e. a failure of individual functions must not result in dangerous conditions. The number of measurement stations that is selected must ensure that the mixtures expected to be present will be detected with sufficient speed and reliability.

The area that is potentially explosive until the safety measures triggered by the warning device take effect must be known. Additional explosion protection measures (preventing ignition sources) are required in this immediate vicinity. The measures triggered by the gas warning device must reliably prevent a dangerous potentially explosive atmosphere from occurring outside of the immediate vicinity.

Gas warning devices must be approved for use in potentially explosive atmospheres in terms of their safety as electrical devices in accordance with Directive 94/9/EC (ATEX 95) and must be identified correspondingly.

The gas warning device as such must be approved, tested and certified as a safety, monitoring and control device in accordance with ATEX 95 if protective measures are introduced by the gas warning device. This can include turning on a ventilation system to limit concentration, but also turning off potential ignition sources (for example electrical equipment).

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3.4.6 Measures for eliminating accumulations of dust

In areas where accumulations of dust must be included in evaluations, the occurrence of a dangerous potentially explosive atmosphere due to stirred up dust can be prevented by preventing dust from accumulating by regular cleaning measures. Cleaning plans must be created for this purpose. They must include above all the scope, nature and frequency of cleaning measures.

Care should be taken that even surfaces that are hard to see or are not readily accessible are cleaned regularly and that when dust is released because of operational malfunctions it is eliminated immediately.

Cleaning processes that stir up dust should be avoided. If vacuum cleaners are used, they must be designed so they are explosion-protected (free of any ignition source).

3.5 Avoiding ignition source – secondary explosion protection

3.5.1 Classification of zones for potentially explosive atmosphere

The basis for evaluating the scope of protective measures is subdividing long-term hazardous areas into zones. The basis for evaluating potentially explosive atmosphere is the frequency and duration of the occurrence of a dangerous potentially explosive atmosphere.

Based on the general conditions, (frequency, duration) potentially explosive gas atmospheres are distinguished and identified by explosion protection zones 0, 1 and 2 and the scope of the measures required to prevent effective ignition sources is specified.

Potentially explosive dust atmospheres are classified accordingly into explosion protection zones 20, 21 and 22.

Standard DIN EN 60079-10 (VDE 0165, part 101) provides help for classification into potentially explosive atmospheres for hazardous areas. However, the collection of examples from explosion protection rules of BG Chemie (BGR 104) will continue to be indispensable for persons involved in practical applications when classifying zones, since they reflect experience gained from previous accidents of great value to practical applications.

In accordance with appendix 3 of the Industrial Safety Regulation of September 27, 2002, potentially explosive atmospheres are defined as follows:

Zone 0 is an area in which a potentially explosive atmosphere as a mixture of air and flammable gases or mists is present permanently, over long periods of time or frequently.

- For example this generally includes the inside of containers or the inside of apparatus (vaporisers, reaction vessels etc.), if the conditions of the definition of Zone 0 are met.

Zone 1 is an area in which a potentially explosive atmosphere may occur occasionally during normal operation as a mixture of air and flammable gases, vapours or mists.

- For example the immediate vicinity of Zone 0, the immediate vicinity of coating openings, the areas close to filling and emptying mechanisms, the areas close to easily breakable apparatus or lines made of glass, ceramic and similar materials, the areas close to stop plugs that are not adequately sealed, for example on pumps and slide valves, and the inside of apparatus such as vaporisers and reaction vessels.

Zone 2 is an area in which a dangerous potentially explosive atmosphere as a mixture of air and flammable gases, vapours or mists does not occur normally or is only of brief duration.

- For example areas surrounding Zone 0 or 1 and certain storage facilities.

Zone 20 is an area in which a potentially explosive atmosphere is present in the form of a cloud made up of combustible dust that is part of the air permanently, over long periods of time or frequently.

- For example: generally this includes only the inside of containers or equipment, for example the inside of grinding mills, dryers, mixers, conveyor lines and silos, etc. if the conditions of the definition of Zone 20 are met.

Zone 21 is an area in which a potentially explosive atmosphere may occur occasionally in the form of a cloud made up of flammable dust that is part of the air.

- For example: the immediate vicinity of coating openings, the area close to filling and emptying equipment and areas where accumulations of dust are present, which occasionally results in a potentially explosive atmosphere when they are stirred up.

Zone 22 is an area in which a potentially explosive atmosphere may occur in the form of a cloud made up of combustible dust that is part of the air. This does not occur normally or is only of brief duration.

- For example: this includes areas in the vicinity of systems containing dust if dust can escape from leaks and form accumulations of dust.

The following illustration is an example of classification in zones for potentially explosive gas atmospheres. The area in question is a tank exposed to open air. The flash point of the liquid is within the range of the average annual temperature and the density of vapours that are given off is greater than that of air.

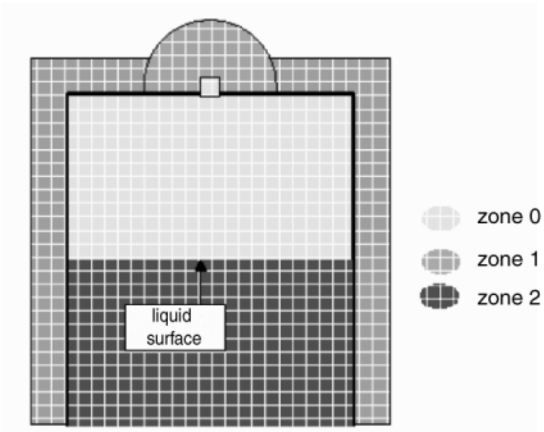

Figure 3.4 Example of zone classification with a tank for flammable liquids
Source: Non-binding introductory manual for well-tried and tested processes relating to executing Directive 1999/92/EC

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The following illustration is an example of classification into zones for a grinding mill with a template container (manual input), product output and filter. In this case, hazardous areas caused by flammable dust are present.

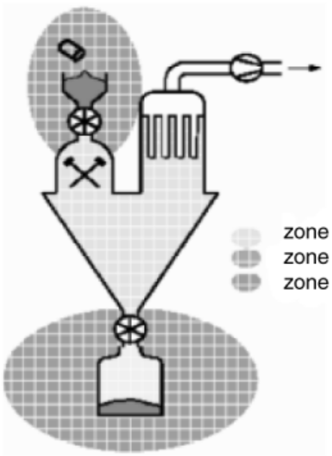

Figure 3.5 Example of classification into zones for flammable dust
Source: Non-binding introductory manual for well-tried and tested processes relating to executing Directive 1999/92/EC

3.5.2 Protective measures against possible ignition sources

When using equipment and when operating systems within potentially explosive atmospheres the operator must check whether ignition hazards may occur. If there is a risk of ignition, an attempt must be made to remove the ignition sources from the hazardous area.

If this is not possible, protective measures must be taken with consideration for the following notes. Protective measures must make ignition sources harmless or must reduce the probability of their becoming effective. This can be achieved by correctly planning and designing devices, protection systems and components and operating processes and by using suitable warning and monitoring systems.

Protective measures in potentially explosive atmospheres against the ignition hazards that occur most frequently are described below. Additional measures, for example protection against dangers due to electromagnetic fields, ionising radiation, ultrasonic waves, adiabatic compression or chemical reactions may be necessary in individual cases.

For more information on various protective measures, please refer to the explosion protection rules of BG Chemie (BGR 104) from which the following description is also taken.

Regardless of the protective measures described here, persons operating systems in potentially explosive atmospheres must perform a definitive evaluation of ignition hazards that must be taken into consideration, in addition to classification into zones.

3.5.2.1 Protective measures against dangers caused by hot surfaces

- In Zone 0, the temperatures of all surfaces of equipment that can come in contact with a potentially explosive (even in the case of operating malfunctions that occur infrequently) must not exceed 80 % of the ignition temperature of a flammable gas or liquid, measured in °C.
- In Zone 1, the temperatures of all surfaces of equipment that can come in contact with a potentially explosive atmosphere must not exceed the ignition temperature of the flammable gas or liquid during normal operation and in the event of operating malfunctions. If the gas or vapour can be heated up to its ignition temperature, however, the surface temperature must not exceed 80 % of the ignition temperature in °C. This value must only be exceeded in the event of operating malfunctions that occur rarely.
- In Zone 2, the temperatures of all surfaces of equipment that can come in contact with a potentially explosive must not exceed the minimum ignition temperature of a gas or liquid during normal operation.
- In Zone 20 the temperature of all surface, that can come in contact with dust clouds must not exceed 2/3 the minimum ignition temperature in °C of the flammable dust cloud, even in the event of operating malfunctions that occur seldom. In addition, the temperature of surfaces on which dust can accumulate must be a safety margin lower than the minimum ignition temperature of the thickest layer of the type of dust in question that can accumulate. This must also be ensured for operating malfunctions that occur rarely. If the thickness of the dust is unknown, the thickest foreseeable layer must be assumed.
- In Zone 21 the temperature of all surface, that can come in contact with dust clouds must not exceed 2/3 the minimum ignition temperature in °C of the flammable dust cloud, even in the event of operating malfunctions. In addition, the temperature of surfaces on which dust can accumulate must be a safety margin lower than the minimum ignition temperature of the thickest layer of the type of dust in question that can accumulate. This must also be ensured for operating malfunctions.
- In Zone 22 the temperature of all surface, that can come in contact with dust clouds must not exceed 2/3 the minimum ignition temperature in °C of the flammable dust cloud during normal operation. In addition, the temperature of surfaces on which dust can accumulate must be a safety margin lower than the minimum ignition temperature of the thickest layer of the type of dust in question that can accumulate.

3.5.2.2 Protective measures against dangers caused by flames and hot gases (including hot particles)

- Devices with flames must not be used in Zones 0 and 20. Gases and flame reactions, for example exhaust gases for the purpose of inertisation and other heated gases can only be introduced into Zone 0 and 20 if special protective measures designed for the individual case in question are used. These special protective measures are related to limiting the temperature, separating out ignitable particles, preventing gas return and flame breakdown, etc.
- Devices with flames are only permitted in zones 1, 2, 21 and 22 if the flames are reliably enclosed and permissible temperatures on the outer surface of system parts is not exceeded. It must further be ensured for equipment with enclosed flames (for example special heating systems) that the enclosure is sufficiently resistant to the effects of flames and flame breakthrough into the hazardous area is reliably prevented. The air required for combustion must only be suctioned out of Zones 1, 2, 21 and 22 if the dangers made possible by suction of a potentially explosive atmosphere are prevented by appropriate protective measures. Hot gases must only be introduced if in addition to the requirements it can be ensured through suitable mechanisms that the exhaust gases do not exceed the ignition temperature of the potentially explosive atmosphere at the entrance point. If flames must be used (for example in ovens), before they are ignited, the possibility that potentially explosive mixtures are present or could occur in dangerous quantities must be excluded.

3.5.2.3 Protective measures against dangers due to mechanically generated sparks

- Work processes (including introducing and operating equipment) are not permitted in Zones 0 and 20, if sparks caused by rubbing, striking or grinding could occur (even if operating malfunctions only occur rarely). In particular, rubbing processes between aluminium or magnesium (except for alloys with less than 10 % Al and paints and coating materials with a weight content of less than 25 % Al) and iron or steel (except for stainless steel if there is no possibility of rust particles being present) must not be permitted. Rubbing and striking processes between titanium or zirconium and any hard material must be avoided.
- In Zones 1 and 21, requirements for Zones 0 and 20 must be met if at all possible. However, if work processes are required in which ignitable sparks caused by rubbing, striking or sanding may occur, sparks must be prevented or shielded through suitable measures. Ignitable sparks caused by grinding may be prevented by water cooling on the grinding spot, for example. Tools and housings made of light metals, including also aluminium, must be avoided since it has been demonstrated that materials such as these can cause sparks, which may be ignitable under conditions of rubbing contact. The occurrence of ignitable sparks caused by rubbing and striking can be limited by selecting suitable combinations of materials (for example for fans). For equipment with parts that are movable during operation, the material combination of light metal and steel (except for non-rusting steel) must be avoided at all possible, rubbing, striking or grinding places. For fans, attention must be paid to selecting suitable material, a suitable rotor bearing and adequate gap dimensions between fixed and rotating parts.
- Generally it is sufficient in Zones 2 and 22 to perform the protective measures described for Zones 1 and 21 against ignitable sparking that can be expected during operation.

Equipment that is intended for use in potentially explosive gas/air and vapour/air atmospheres or in flammable mist and that can generate sparks through mechanical effects, must not be used in any zone if the potentially explosive atmosphere may contain one or more of the following gases: acetylene, carbon sulphide, hydrogen, hydrogen sulphide, or ethylene oxide.

3.5.2.4 Protective measures against dangers caused by electrical systems

- Only electrical devices of category 1 G may be used in Zone 0.
- Only electrical devices of category 1 G or 2 G may be used in Zone 1.
- Only electrical devices of category 1 G, 2 G or 3 G may be used in Zone 2.
- Only electrical devices of category 1 D may be used in Zone 20.
- Only electrical devices of category 1 D or 2 D may be used in Zone 21.
- Only electrical devices of category 1 D, 2 D or 3 D may be used in Zone 22.

3.5.2.5 Protective measures against dangers caused by equalisation currents

- In Zones 0 and 20, in addition 21, potential equalisation is required for all conducting parts of the system – thus those that are not close to electrical equipment. The potential equalisation must be designed according to DIN EN 60079-14 (VDE 0165, part 1). Deviation from this requirement is possible within areas that are enclosed by conducting walls that are included in potential equalisation. If conducting parts of the system are brought into Zone 0, 20 or 21, for example ventilation or suction pipes into tanks, they must previously have been included in the potential equalisation.
- Protective measures are required In Zone 1 as in Zone 0. However, there is no need for special measures of potential equalisation on conducting parts of the system that are not close to electrical equipment, for example additional jumpers, if there is already an equalisation current due to highly intermeshed parts of the system capable of conducting a current, for example pipe networks or extended grounding systems.

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- Generally there is no need for potential equalisation in Zones 2 and 22 unless light arcs or sparks emanating from equalisation currents occur frequently.
- If electrical equipment is used in Zone 2, potential equalisation in accordance with DIN EN 60079-14 (VDE 0165, part 1) is required.

3.5.2.6 Protective measures against dangers caused by static electricity

For the required protective measures, please refer to the "Guidelines for preventing ignition hazards caused by electrostatic charge" (BGR 132).

The most important protective measure is grounding all conducting parts that could acquire a dangerous charge. However, this protective measure is not always sufficient to prevent ignition hazards. Much more frequently, dangerous charges of non-conducting parts and substances or the ignition hazards caused by them must be prevented.

- Ignitable discharges must also be prevented in Zones 0 and 20, even taking into account operating malfunctions that occur rarely.
- Ignitable discharges during proper operation of systems, including maintenance and cleaning and during operating malfunctions that must typically be counted on, must be prevented in Zones 1 and 21. (For example, dangerous discharges from insulator surfaces caused by an increase in the surface conductivity or relative humidity of at least 65% must be prevented).
- Generally, measures are not required in Zones 2 and 22 unless ignitable discharges occur continuously (for example with drive belts that are not sufficiently conductive).

Protective measures against dangers caused by lightning strike

If there is a risk of lightning strike, the following requirements must be met for all zones:

Systems must be protected through suitable lightning protection measures.

Harmful effects of lightning strikes that take place outside of Zones 0 and 20 on Zones 0 and 20, must be prevented i. e. overvoltage siuppressors should be installed at suitable places, thus outside the potentially explosive area. Potential equalisation is required for tank systems or electrically conducting systems electrically insulated against the container that are covered by earth, for example in the form of and ground ring lead.

Pepperl+Fuchs GmbH makes overvoltage suppressors (lightning protection barriers) available for mounting on DIN carrier rails, screw mounting for field devices and a a plug-on housing for DIN rail housing.

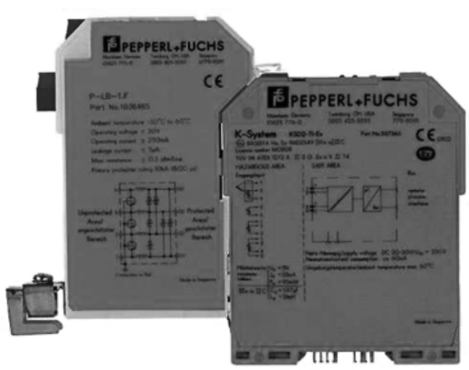

Figure 3.6 Overvoltage suppressor with plug-in housing for DIN rail housing

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3.6 Limiting the effects of an explosion to an acceptable degree

If primary or secondary explosion protection measures according to 3.4 and 3.5 cannot be performed or would not be effective, design-based measures must be taken to limit the effects of an explosion to a negligible level. This can be achieved by:

1. Explosion-proof design
2. Explosion pressure release
3. Explosion suppression
4. Preventing transfer of the explosion

Devices and protection systems that are intended to ensure design-based explosion protection, must meet the requirements of Directive 94/9/EC.

3.6.1 Explosion-proof design

System parts such as containers, apparatus, and pipe lines designed so that they can withstand an explosion internally without tearing apart. A distinction is made between explosion pressure-proof design and explosion pressure shock-proof design.

Explosion pressure-proof containers and apparatus can resist the excess pressure of the anticipated explosion without being permanently deformed. The anticipated explosion pressure is used as the basis for the calculation pressure.

In the explosion pressure shock-proof design, containers and apparatus are designed so that they can internally withstand the pressure shock at the level of the anticipated excess explosion pressure. Permanent deformation is permitted in this case, however.

3.6.2 Explosion pressure release

"Explosion pressure release" means all measures used when an explosion occurs or reaches a certain stage of expansion to open briefly or permanently the apparatus that was originally closed off in a direction that is not dangerous when the trigger pressure is reached. The purpose of the pressure relief mechanism is to prevent the apparatus from being loaded beyond its explosion-proof capacity.

The pressure relief device could be rupture disks, for example or explosion flaps. These must meet the requirements of Directive 94/9/EC as protection systems.

When attaching pressure relief mechanisms to apparatus, care must be taken that the pressure release is in a direction that is not dangerous. Injury to persons (for example due to the effects of pressure and flames or parts that are forcibly ejected) must be avoided, as must damage to the environment (for example by releasing toxic substances).

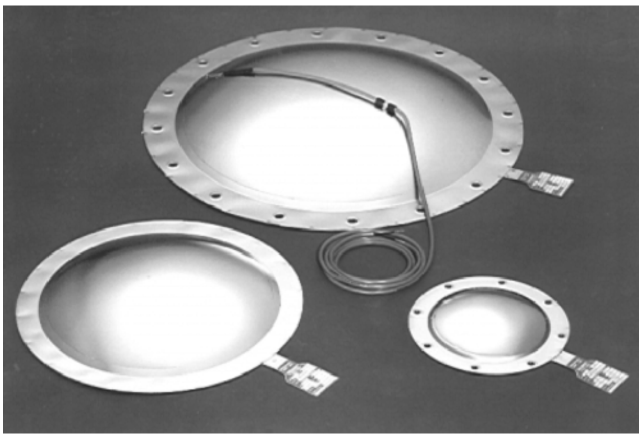

Figure 3.7 Rupture disk (source REMBE GmbH SAFETY + CONTROL)

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3.6.3 Explosion suppression

The principle of explosion suppression is based on preventing the maximum explosion pressure from being achieved by rapid inflation of containers and apparatus with extinguishing agents in the event of an explosion. Systems protected in this manner thus need to be designed only for a reduced explosion protection.

Explosion suppression devices must meet the requirements of Directive 94/9/EC as protection systems.

3.6.4 Preventing transfer of an explosion (explosion-related decoupling)

If an explosion occurs in a part of a system, it can expand into the upstream or downstream parts of the system. Additional explosions may occur as a result of this, whose effects can be reinforced by acceleration effects, by installed components or by spreading through pipes. The explosion pressures resulting from this can be greater than the maximum explosion pressure under normal conditions and may result in destruction of system parts, even if the design is explosion-proof. Explosion-based decoupling can thus ensure that possible explosions are limited to individual system parts.

Explosion-related decoupling devices must also meet the requirements of Directive 94/9/EC as protection systems.

The way in which flame breakthrough-proof devices work is based essentially on one or more of the following mechanisms:

- Extinguishing flames in narrow gaps and channels (for example strip fuses, sintered metals),
- Stopping a flame front by a causing unburned mixtures to flow out at a correspondingly high speed (high-speed valves),
- Stopping a flame front with liquid collecting containers (for example immersion fuses or liquid stops).

Depending on how long a device exposed to flame breakthrough can resist the effects of the flame without losing its protection against breakdown, fittings are identified as explosion-proof, long-term fireproof and detonation-proof.

In the case of dust, flame breakdown-proof devices cannot be used for gases, vapours or mist due to the risk of plugging up. In practical applications, dust explosions have been prevented from expanding by the following decoupling devices:

- Extinguishing agent block
- Quick-closing slide valve, quick-closing flap
- Quick-closing valve (explosion protection valve)
- Rotary feeder
- Pressure relief flue
- Product template
- Double slide valve

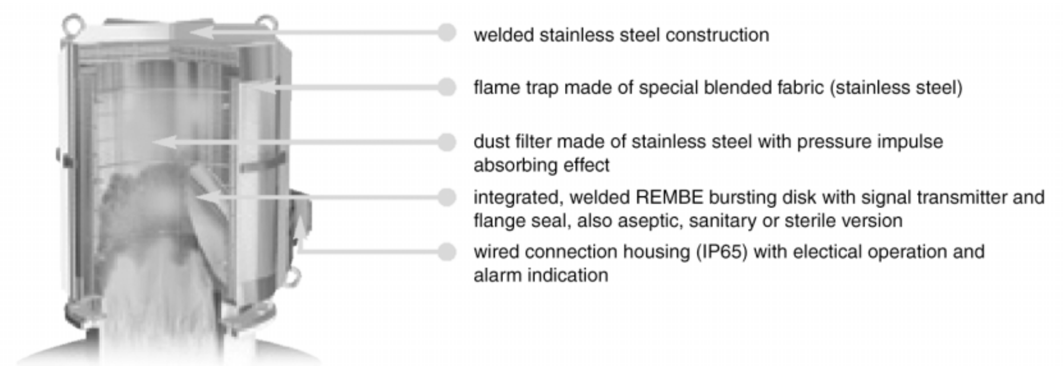

Figure 3.8 ECO-Q tube (Source REMBE GmbH SAFETY + CONTROL)

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3.7 References

BetrSichV	"Regulation regarding Safety and Health Protection in Providing Work Equipment and its use in Work, Safety in Operating Systems Requiring Monitoring and the Organisation of Industrial Work Protection"(Industrial Safety Regulation).
GefStoffV	Regulation for Protection from Hazardous Substances (in German: Gefahrstoffverordnung)
ExVO	Eleventh regulation on the Device Safety Law (regulation on placing devices and safety systems in circulation for hazardous areas – explosion protection regulation – 11th GSGV)
ATEX 137	Directive 1999/92/EC of the European Parliament and Council of December 16, 1999 regarding minimum requirements for improving health protection and safety of employees who may be endangered by a potentially explosive atmosphere.
ATEX 95	Directive 94/9/EC of the European Parliament and Council of March 23,1994 for harmonising statutory requirements of member nations for devices and protection systems intended for use in potentially explosive atmospheres
DIN EN 1127-1	Potentially explosive atmosphere – explosion protection, part 1: basic principles and methodology
BGR 104 (earlier ZH 1/10)	"Rules for Safety and Health Protection at Work" Explosion protection rules (EX-RL)
BGR 132 (earlier ZH 1/200)	Directives for preventing ignition hazards resulting from electrostatic charge – "Static Electricity" Directive
DIN VDE 0100	Setting up high-voltage systems with nominal voltages up to 1000 V
DIN EN 60079-10 (VDE 0165, part 101)	Electrical equipment for explosive gas atmospheres, part 10: Classification of explosive gas hazardous areas
DIN EN 60079-14 (VDE 0165, part 1)	Electrical equipment for explosive gas atmospheres part 14: Electrical systems in hazardous areas (except for underground construction)
DIN EN 60079-17 (VDE 0165, part 10)	Electrical equipment for explosive gas atmospheres part 17: Testing and maintaining electrical systems in potentially explosive atmospheres (except for underground construction)
DIN EN 50281-1-2 (VDE 0165, part 2)	Electrical equipment for use in areas with flammable dust Main section 1: Electrical equipment with protection through housing Part 2: Selection, set-up and maintenance
Non-binding introductory manual	for well-tried and tested processes relating to executing Directive 1999/92/EC Revised draft version October 2002
Electrical explosion protection in accordance with DIN VDE 0165	Lienenklaus/Wettingfeld: Electrical explosion protection in accordance with DIN VDE 0165; VDE series 65, 2., revised edition 2001, VDE Published by VDE, Berlin and Offenbach

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4 Overview of ignition protection classes for hazardous explosive gas environments

4.1 General requirements (EN 50014)

As a basic standard on ignition protection classes, "DIN EN 50014 Electrical equipment for hazardous areas, General requirements" defines the term "Ignition protection class" as special measures that are taken with electrical equipment to prevent the ignition of potentially explosive atmospheres in the vicinity.

In other words, this means explicitly that standards describing ignition protection classes specify what the manufacturer of electrical equipment must observe for use in potentially explosive atmospheres, during design, development, production, individual testing and marking so that the equipment in question can be used in hazardous areas. The responsibility for this is the manufacturer's.

In spite of this it is important for the user or installer to be familiar with the basic principles of ignition protection classes and detailed knowledge is even required for installation of individual pieces of explosion-protected equipment. This applies to the ignition protection classes flameproof enclosure, increased safety, intrinsic safety and pressurising systems. DIN EN 60079-14 VDE 0165, part 1 specified "additional requirements" during installation for these ignition protection classes.

DIN EN 50014: 2000-02 must not be applied until March 1, 2007. Standard DIN EN 60079-0 (VDE 0170/0171, part 1) has been in force since December 1, 2004. DIN EN 60079-0 refers to the following standards that describe types of ignition protection which are also adapted to the numbering of international standards:

IEC 60079-1	Fire Proof Enclosure "d" (DIN EN 50018)
IEC 60079-2	Excess Pressure Enclosure "p" (DIN EN 50016)
IEC 60079-5	Sand Enclosure "q" (DIN EN 50017)
IEC 60079-6	Oil Enclosure "o" (DIN EN 50015)
IEC 60079-7	Increased Safety "e" (DIN EN 50019)
IEC 60079-11	Intrinsic Safety "i" (DIN EN 50020)
IEC 60079-15	Ignition Protection Type "n" (DIN EN 50021)
IEC 60079-18	Cast Enclosure "m" (DIN EN 50028)
IEC 60079-25	Intrinsically Safe Systems (DIN EN 50039)

The introduction to DIN EN 60079-0 recognises that with the progress of technological development it will be possible to reach the goals of standard series IEC 60079 in reference to avoiding explosions by procedures that are not yet fully determined. Taking various conditions into consideration, the letter "s" is reserved as a designation of this protective procedure.

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Several years ago there was a comprehensive revision of IEC 60079-0 in the relevant standards committees. Important aspects are:

- Incorporation of dust explosion protection in the previous standard "General requirements – Electrical apparatus for areas endangered by gas explosion"
- Associated with this are the acceptance of the definitions from IEC 61241-0 for the dust explosion protection and the expansion of the working media/operating means groups.

  The working media group III (Electrical media for areas with an explosive dust atmosphere) is added to the existing groups I and II.

  Analogous to the sub-division of group II into IIA, IIB and IIC, group III is categorised in terms of the tendency to ignite of the dust-air mixture, as follows:
  - IIIA – ignitable fibres and fluff
  - IIIB – non-conductive dust
  - IIIC – conductive dust.
- Introduction of the Equipment Protection Level (EPL). By this is understood the level of protection of a device, which depends on the established risk of the build up of ignition sources and the various conditions imposed by gas and dust atmospheres, both above ground and in mining operations.

At the latest on consideration of the new designations for operating means in the ignition protection categories of intrinsic safety or encapsulation, where "ia", "ib", "ic", "ma", "mb" and "mc" emerge, or in the most unfavourable case of the "pressurised enclosure", where "px", "py" and "pz" emerge, it should be possible for the user to be clear what is involved in the new designations. The closeness of the category contents to those defined in the ATEX guidelines is exemplified by the definition of protection level (EPL) Ga.

EPL Ga – Devices for use in gas atmospheres susceptible to explosion, which have a "very high" level of protection and no ignition sources in normal operation due to anticipated device faults and the possibility of ignition sources only in very rare fault cases. The ignition protection category of these devices is maintained even in the event of two faults (e. g. intrinsic safety ia) or is based on two independently effective ignition protection categories. [4]

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The principle and application of various ignition protection classes are illustrated below in a table.

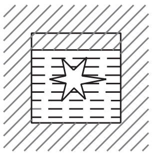
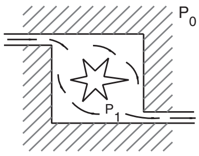
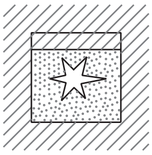
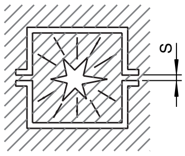
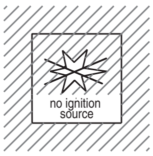
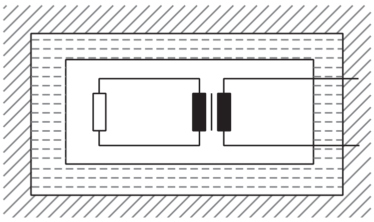
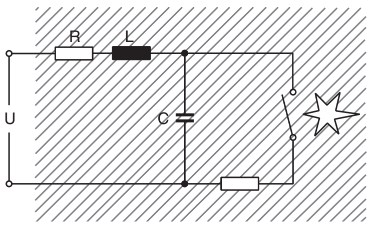
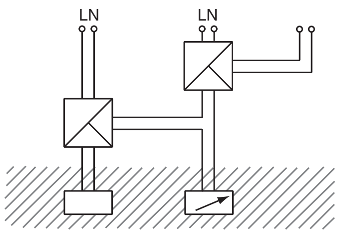
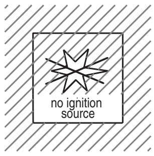
Ignition protection class	Conventional symbol hatched = Hazardous area	Working principle, application
Oil enclosure "o"		The ignition source is continuously enclosed in oil. Usage with switching devices and transformers.
Pressurising systems "p"		An ignition protection gas that is under excess pressure ($p_0 < p_1$) and encloses the ignition source. Use with machines and commutator motors, switch cabinets, measurement stations, monitors, keyboards and analysis devices
Sand enclosure "q"		The fine-grained filling material encloses the ignition source. A light arc inside must not ignited the Ex atmospheres surrounding the housing. Use with capacitors, pre-switching devices for lights and measuring instruments.
Flameproof enclosure "d"		In the case of an ignition inside the enclosure, the housing must resist the pressure and there must be no possibility of a transfer of the "internal" explosion to the outside (s gap width). Use in high-voltage systems, switching devices, parts generating sparks.
Increased safety "e"		Measures to reduce the probability of spark formation and increased temperature. There must be no ignition source present in normal operation. Use in connection systems (motors).
Cast enclosure "m"		The ignition source is embedded into the cast body in such a manner that it cannot ignite a hazardous potentially explosive atmosphere. Use with measuring instrument and control drives.
Intrinsic safety "i"		Power in the circuit is limited to levels that do not allow for any impermissibly high temperatures and/ or ignition sparks or light arcs that have the ignition power required for an explosion. Use of MSR systems.
Intrinsically safe systems "i-SYST"		All electrical equipment that is interconnected, documented by a description of the system. Circuits that are used entirely or partially in the hazardous area are intrinsically safe circuits.

Table 4.1 The principle and application of various ignition protection classes

4.2 Abbreviated characteristic of ignition protection classes

4.2.1 Ignition protection class "Increased safety"

DIN EN 600079-7 (VDE 0170/0171, part 6): 2004-04



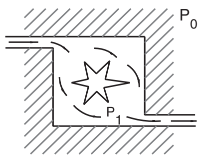
"Ignition protection class in which measures are taken with an increased level of safety to prevent the possibility of impermissibly high temperatures from and the occurrence of sparks or light arcs inside or on outer parts of electrical equipment in which these do not occur in normal operation."

Special value is placed for equipment of this ignition protection class on:

- Increased operating and base isolation
- Good design and construction in terms of safety
- Terminals that prevent wires from coming loose by themselves
- Overload protection
- A secure connection for incoming lines and
- Sufficient mechanical protection.

4.2.2 Ignition protection class "Pressurising system"

DIN EN 60079-2 (VDE 0170/0171, part 3): 2005-02



"An ignition protection class in which an ambient atmosphere is prevented from penetrating inside the housing of electrical equipment by an ignition protection gas (air, inert gas or some other suitable gas) by an excess pressure compared to the surrounding atmosphere. The excess pressure is maintained with or without ongoing rinsing of ignition protection gas".

EN 50016 distinguishes 2 different types of pressurising systems:

- Pressurising systems with continuous rinsing of ignition protection gas. In addition to acting as an ignition protection measure, the constant rinsing serves to draw away escaping heat.
- Pressurising systems with compensation for pressure losses.

This ignition protection class allows the planner or operator of electrical systems to solve complex problems on site that are not possible when using other ignition protection classes. These special arrangements are still possible through article 8 Paragraph 5 of ATEX 95 and § 4 paragraph 5 of ExVO.

The new version of EN 50016 includes the design types for static pressurising systems (*maintaining proper excess pressure within a pressuring housing system without supplying ignition protection gas in hazardous areas*); the containment system (*part of the equipment, containing flammable gas, flammable vapour or flammable liquid and able to form an internal point from which one of those can escape*) and internal escape points (*a point from which a flammable material could penetrate into the pressurised housing enclosure as gas, vapour or liquid so that if air is present a potentially explosive atmosphere can be formed*).

In addition, the term "safety-related control system" is introduced. This refers to certified control systems, for example for pressure monitoring and pre-rinsing of housings in pressurising systems. These related safety monitoring systems must not be installed in hazardous areas without an additional ignition protection class. [1]

DIN EN 60079-2 is valid as of February 1, 2005. This new standard contains extensive new elements, which are of course too detailed for a description here. Important innovations include defining ignition protection types "px", "py" and "pz". They were already referred to in the new DIN EN 60079-0 under the section "Marking".

Ignition protection by flameproof enclosure is divided into three ignition protection types ("px", "py", "pz"), which are selected based on a possible external explosive atmosphere (group I, Zone 1 or Zone 2), in other words whether there is a possibility of internal discharges and whether the equipment can be ignited in the flameproof enclosure housing. For additional information, see the table on Seite 66.

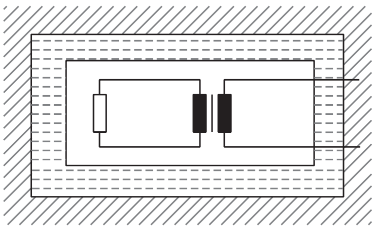
Flameproof enclosure type "px" Flameproof (excess pressure) enclosure that reduces the classification within the flameproof enclosed housing from Zone 1 to "not explosive" or from group I to "non-explosive".

Flameproof enclosure type "py" Flameproof enclosure that reduces the classification within the flameproof enclosure from Zone 1 to Zone 2.

Flameproof enclosure type "pz" Flameproof enclosure that reduced the classification within the flameproof enclosure from Zone 2 to "not explosive".

4.2.3 Ignition protection class "Cast enclosure"

DIN EN 60079-18 (VDE 0170/0171, part 9): 2005-01



"An ignition protection type in which the parts that could ignite an explosive atmosphere by sparking or heating up are embedded in a fixed mass in such a manner that the explosive atmosphere cannot be ignited under operating or installation conditions."

In the cast enclosure ignition protection class, equipment that can be located in hollow areas is enclosed by a suitable and tested cast body so that it seems impossible for a potentially explosive atmosphere to penetrate into the hollow area. The hollow area in a piece of equipment of the cast enclosure ignition protection class may be up to 100 cm^3.

The cast enclosure ignition protection class is suitable for contactors, relays, incremental switching mechanisms and components that do not contain any movable parts such as resistors, inductances, capacitances, fuses and printed circuit boards with electrical circuits.

DIN EN 60079-18 specifies that electrical devices of ignition protection type cast enclosure "m" should be categorised either in protection level "ma" or "mb".

"m" devices with protection level "ma" must not cause an ignition under any of the following cases:

a) under normal operating and installation conditions

b) under all specified abnormal conditions

c) under defined error conditions.

To determine whether these cast enclosed devices meet the requirements of category 1 with protection level "ma" and consequently can be installed in Zones 0 or 20, see the corresponding prototype test certifications and marking.

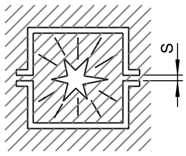
"m" devices with protection level "mb" must not cause an ignition under any of the following cases:

a) under normal operating and installation conditions

b) under defined error conditions.

4.2.4 Ignition protection class "Flameproof enclosure"

DIN EN 60079-1 (VDE/0170/0171, part 5): 2004-12



"An ignition protection class in which the parts that are able to ignite a potentially explosive atmosphere are arranged in a housing that can withstand internally the pressure resulting from the explosion of a potentially explosive and will prevent the explosion from spreading into the potentially explosive atmosphere surrounding the housing".

The housing is not designed to be sealed against gases. Instead it is equipped with an ignition breakdown safety gap that acts as an opening to relieve pressure. Penetrating hot gases are cooled down so much that they cannot ignite the explosive atmosphere outside the housing. Ignition is prevented if the minimum ignition temperature and the minimum ignition power of the surrounding potentially explosive atmosphere are not reached. For this reason, the appliances of this ignition protection class for the explosion groups I, IIA, IIB, IIC are approved with different minimum gap lengths and maximum gap widths (cf. Table 1 and 2 of EN 50018) depending on the type of gap.

The most important detail of ignition protection class EEx d is the ignition breakdown safety gap that must not be either enlarged (rough removal of rust) or reduced (greasing with grease containing resin).

If equipment protected by a flameproof enclosure is used, the installation of electrical leads is generally made using the "increased safety" ignition protection class.

n the case of switching devices the most important ignition protection category is the "flameproof enclosure", in which the switching devices can be of 3 different types of construction [5]:

- Encapsulated housing, in which one or a number of industrial switching devices, e. g. relays, contactors, circuit breakers and other components are built into a universally used housing, consisting of a device installation compartment in a "flameproof enclosure" and the connection compartment in "increased safety" (indirect installation method).
- Component encapsulation, in which the electrical device, wired using an indirect method of installation, is individually encapsulated in a housing specially constructed for this application. The installation of a device in an Ex e housing provides a completely explosion-protected electrical apparatus.

- Individual contact encapsulation, in which only the switching chamber, in which the ignition sparks or the arc occur, is flameproof encapsulated. Even for this type of encapsulation it is still the case, that electrical connection and disconnection is only possible in the voltage-free condition. In the case of currents up to a maximum of 10 A and voltages of 250 V AC or 60 V DC, in accordance with IEC 60079-0 plug-and-socket devices that differ from these requirements can still be used if the plug device cuts out the rated current with a time delay, such that no arcing can occur on disconnection and if during phase in which the arc extinction takes place the flameproof encapsulation remains effective.

The multi-function terminal from Pepperl+Fuchs GmbH, Mannheim provides a solution, by means of which the regimentation of the ignition protection categories Ex d and Ex e (no maintenance and installation work in Zone 1) and the restrictions of the ignition protection category Ex i (low current, therefore maintenance and installation work in Zone 1 even with an explosive atmosphere, without switching off the system) are circumvented by the technical features incorporated in the device.

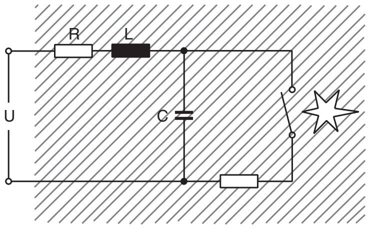
Figure 4.1 Construction of the multi-function terminal

The principle of the energy connector is as follows:

- In the first step the connector is pulled out
- In the second step the resulting spark is extinguished
- In the third step the Ex e-terminal is accessible on removal of the plug module and thus no hot work permit is required.

4.2.5 Ignition protection class "Intrinsic safety"

DIN EN 60079-11 (VDE 0170/0171, part 7): 2003-08



Intrinsic safety does not refer to a single piece of equipment, but rather to the entire intrinsically safe circuit. It is therefore important to cite the explanation of the term intrinsic safety:

"A circuit in which neither sparking nor a thermal effect that occurs under the conditions specified in this standard, which include operation without any malfunctions and certain failure conditions, is able to cause an ignition of a specific potentially explosive atmosphere".

This intrinsically safe circuit includes, in addition to the interface cables, at least one intrinsically safe piece of equipment and one related piece of equipment.

Intrinsically safe equipment

This is a piece of equipment for which all circuits are intrinsically safe according to the definition. The voltage and current in the intrinsically safe circuit are so low that no ignition takes place in the even of a short circuit or ground fault, i. e. the ignition power remains less than the minimum ignition power.

In contrast to related equipment, intrinsically safe equipment is suitable for operation directly in hazardous areas.

Figure 4.2 Electrical equipment in ignition protection class "Intrinsic safety"

Related equipment

The related equipment is a piece of equipment in which not all circuit are intrinsically safe. However, it does contain at least one intrinsically safe circuit that can be directed into the potentially explosive atmosphere. Generally it converts an intrinsically safe signal into a non-intrinsically safe signal. The flow of current can lead into the potentially explosive atmosphere or come out of it at this point. Related equipment is available as simple signal separators or signal transforming devices. Signal separators are typically referred to as safety barriers, signal transforming devices as measurement converters, switch amplifiers, current repeaters, etc.

A piece of related equipment can be either:

a) electrical equipment with another ignition protection class listed in European standard EN 50014 suitable for use in potentially explosive atmospheres or

b) electrical equipment that is not appropriately protected and therefore must not be used inpotentially explosive atmospheres, for example a recording device that is not located in the hazardous area itself but is connected to a thermoelement located in the hazardous area and only the input current of the recording device is intrinsically safe. [2]

The marking of a piece of related electrical equipment should always have pointed brackets around it

in case a) EEx d [ia] IIB T6,

in case b) [EEx ia] IIC.

In case b there is no need to specify the temperature class, since the electrical equipment cannot be installed in the hazardous area.

The Intrinsic Safety ignition protection class will be discussed elsewhere in detail.

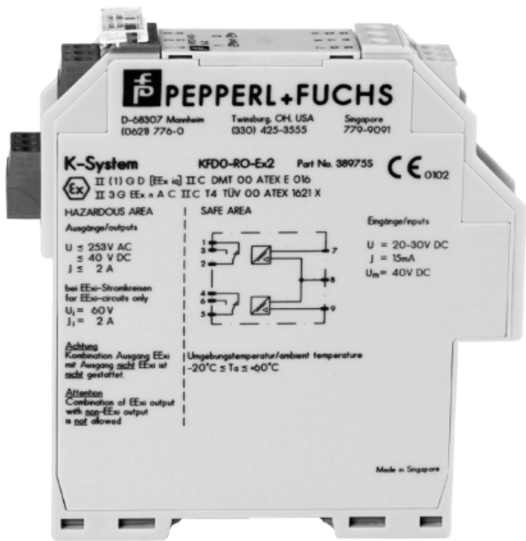


Figure 4.3 Related intrinsically safe equipment

4.2.6 Ignition protection class "n"

DIN EN 60079-15 (VDE 0170/0171, part 16): 2003-12

"Ignition protection type electrical equipment in which it is ensured in normal operation and under specific abnormal conditions that the equipment is not capable of igniting an ambient explosive atmosphere."

A note has been added to the standard stating that the requirements of the standard are intended to ensure that it is unlikely an error capable of causing an ignition could occur.

This European standard describes the requirements for equipment to be used in Zone 2. These include:

- Non-sparking electrical equipment
- Equipment with parts or circuits that may induce light arcs, sparks or hot surfaces (and which could therefore be capable of igniting a potentially explosive atmosphere if they are unprotected).

In addition to EEx n, the marking includes an abbreviation referring to the supplementary protective measures:

A: Non-sparking equipment

C: Sparking equipment contacts in suitable manner, but not by R, L, Z, protected

R: Restricted-breathing housing

L: Limited power equipment

Z, P: Simplified pressurising system

The power limit is based on the basic concerns of intrinsic safety. Intrinsically safe circuits are calculated with a safety factor of 1.0.

EN 60079-14 describes (in section 5.2.3 "Equipment for use in Zone 2") the basic requirements for this equipment without requiring that an EC declaration of conformity be present. If the manufacturer of equipment for use in Zone 2 manufactures it in conformity with EN 50021, a statement of conformity is sufficient documentation for this device. ATEX 95 does not require any EC declaration of conformity for Zone equipment 2. Instead, it requires only internal manufacturing control in accordance with appendix VIII of the directive. This equipment ensures a significantly higher level of safety than standard devices of good industrial quality.

EN 60079-15 describes possible protective principles of ignition protection class "n". They are summarised in the table below. [3]

"n" equipment	Examples of protection methods	Marking
Non-sparking (simple "increased safety")	Electro-motors (squirrel cage rotor), terminal box, fuses, lights, transformers, equipment with low power (MSR systems), plug-in devices, cells, batteries, etc.	EEx nA
With protected contacts	Simple "flameproof enclosure" or simple "cast enclosure"	EEx nC
Enclosed mechanism	Same	
Part not capable of igniting	Contact mechanism or housing designed so as to prevent ignition.	
Hermetically sealed device	Seal ensured by a melting process such as soft or hard soldering, welding or melting glass into metal.	
Sealed device	Designed so that it cannot be opened during normal operation.	
Enclosed device	Completely embedded in an enclosing cast body.	
Restricted breathing	Housing design limits penetration of gases and vapours. Only sparking equipment with an internal temperature $\leq$ 10 K compared to the ambient temperature of the housing can be installed.	EEx nR
Limited power (simple "intrinsic safety")	Limit power on circuits and components in accordance with the intrinsic safety concept.	EEx nL
Simple "pressurising system"	Pressurising systems not subject to pre-rinsing, which display an error if the excess pressure drops. However, the system does not need to be turned off immediately.	EEx nZ, nP

Table 4.2 Possible protective principles of ignition protection class "n"

In the context of the restructuring of the standards for the ignition protection categories it is to be expected that only the categories EEx nA and EEx nR will remain for use for apparatus in Zone 2. EEx nC is taken over into IEC 60079-18 encapsulation as Ex mc, EEx nL in IEC 60079-11 as intrinsic safety Ex ic and EEx nP in IEC 60079-2 as pressurised enclosure Ex pz.

4.2.7 Ignition protection class "Intrinsically Safe Systems"

DIN EN 60079-25 (VDE 0170/0171, part 10-1): 2004-09

An intrinsically safe electrical system is a module consisting of a number of pieces of electrical equipment connected with each other. They are illustrated in the system description. Circuits or parts of circuits that are designed for use in a hazardous area are intrinsically safe circuits in these areas. Every intrinsically safe system must be assigned to either protection level "ia" or "ib".

A certificate is issued for a certified intrinsically safe system. A non-certified intrinsically safe system is an electrical system in which knowledge of the electrical parameters of the intrinsically safe electrical equipment used, the corresponding certified equipment, simple equipment and knowledge of the electrical and physical parameters of connection lines make it possible to determine clearly that intrinsic safety is ensured.

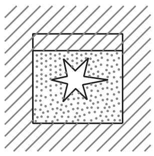
Several annexes of this standard are very important when setting up certified intrinsically safe systems:

Annex A:	Evaluation of a simple intrinsically safe system
Annex B:	Evaluation of circuits with more than one electrical power source
Annex C:	Combining non-linear and linear intrinsically safe circuits (see PTB report ThEx-10)
Annex D:	Verification of inductive characteristic values
Annex F:	Excess voltage protection of an intrinsically safe circuit

Annexes A and B are normative, while annexes C, D, F are informative.

4.2.8 Ignition protection class "Sand enclosure"

DIN EN 60079-5 (VDE 0170/0171, part 4): 2000-02



"Ignition protection type in which the parts of a piece of equipment that could result in an ignition are permanently arranged in their position and are completely surrounded by filling material to prevent an ignition of an external explosive atmosphere."

This standard only applies to categories 2G and M2.

The filling must be designed so there are no hollow areas remaining inside the filling material. The free volume inside the sand enclosure of electrical equipment, part of a piece of electrical equipment or Ex module must be completely filled with the filling material.

For example, the combination of ignition protection types "q", "i" and "e" is used when manufacturing computers for control, operation and viewing of process data in hazardous areas.

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Figure 4.4 Ex-q Computers PCEX 410-.... (Source: Pepperl+Fuchs-Extec GmbH)

This computer identified as ⟨Ex⟩ II 2G EEx qe [ib] IIC T4 consists of a metal housing with a front plate and filled with glass balls. The device contains modules with intrinsically safe outputs for peripheral devices. Non-intrinsic data signals are connected via integrated interface barriers.

In the current process of assigning standards consideration is given to the possibility, under certain conditions, of opening the housing for the purpose of repair. After refilling with sand the housing has to be resealed. The disadvantage of "non-repairable" would be avoided and a favourable alternative to the "non-repairable" encapsulation would be created. [4]

4.2.9 Ignition protection category "Oil immersion"

DIN EN 50015 (VDE 0170/0171, part 2): 2000-02

This ignition protection category will not be treated in detail in the manual.The following note has been issued by the standards committee:

"Thus far oil immersion has been regarded more or less as a museum item. The question that has to be resolved is whether the standard should be withdrawn or updated." [4]

4.3 Additional stipulations of EN 50014

DIN EN 60079-0 (VDE 0170/0171, part 1): 2004-12

4.3.1 Classification of equipment into groups

Group I: Electrical equipment for firedamp protected mining construction

Group II: Electrical equipment for all potentially explosive atmospheres except mines susceptible to firedamp.

The categorisation of explosion groups II is based on the properties of the potentially explosive atmosphere for which the equipment is intended. This categorisation of explosion group II is required for ignition protection classes that do not provide for any separation of possible ignition sources from the dangerous potentially explosive atmosphere.

The ignition protection class Flameproof Enclosure "d" brakes down flammable gases and vapours based on their ignition breakdown capacity by column and according to the minimum ignition current ratio for intrinsic safety "i".

The more readily the flammable gases and vapours ignite, the less the maximum permitted gap or minimum ignition current need to be.

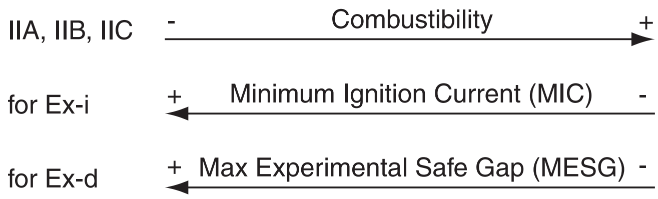

Figure 4.5 Dependance between combustibility, minimum ignition current and max. experimental safe gap of gases and vapours

Appendix A of EN 50014 contains by way of example an assignment of flammable gases and vapours to explosion groups IIA, IIB, IIC.

The subdivision of flammable gases and vapours also applies to ignition protection types "nC" and "nL".

4.3.2 Categorisation of temperature classes

Electrical equipment in compliance with DIN EN 60079-0 is designed for use in areas where the danger of explosion is caused under the normal climate conditions listed below by mixing air with gases, vapours and mists:

Temperature -20 °C to +60 °C,

Pressure 80 kPa (0.8 bar) to 110 kPa (1.1 bar) and

Air with normal oxygen content, typically 21 % (V/V).

The definition of maximum surface temperature is based on an ambient operating temperature of -20 °C to +40 °C.

If the maximum surface temperature of a piece of equipment reaches the ignition temperature of the surrounding atmosphere that is capable of igniting, an ignition can occur. Because of this, all electrical equipment is divided into temperature classes. The lowest ignition temperature of the potentially explosive atmosphere in question must be greater than the maximum surface temperature (special specifications apply to surfaces of not more than 10 cm^2 altogether).

The temperature classes apply to an ambient area of from -20 °C to +40 °C. EN 50014 requires additional marking by the symbol "T_a" or "T_{amb}" for use in another temperature range.

Group I:	150 °C (with possible accumulations of coal dust) 450 °C (without risk of coal dust accumulations)
Group II:	Assignment of maximum surface temperature to temperature classes
Temperature class	Max. surface temperature [°C]
T1	450
T2	300
T3	200
T4	135
T5	100
T6	85

Table 4.3 Categorisation of temperature classes

Note

Equipment for use in explosive dust atmospheres is not categorised by temperature classifications in terms of its surface temperature. For these devices, the highest surface temperature is specified. It must be reduced by 1/3 if there is danger caused by a dust cloud or by 75 K in the event of ignition hazard due to an accumulation of dust. The considerations required for these figures are discussed in more detail elsewhere.

4.3.3 Marking of electrical equipment

The marking that has been prescribed for many years now is specified in DIN EN 50014. This marking, referred to as the technical marking or identification remains in place. In addition to these requirements, ATEX 95 and its implementation through ExVO also contain an "ATEX marking".

Appendix II of ATEX 95 requires the following under "basic requirements":

- Name and address of the manufacturer
- CE-Marking,
- Identification of series and type, year of manufacture and if applicable the serial number
- The Identifier Ex together with the identifier referring to the category (1/2/3)
- The letter G (gas) or D (dust) to identify the potentially explosive atmosphere

This information must all appear on the device. The advantage of this innovation is that if clearly indicates the zone in which it is appropriate to use the device in question.

In addition, and if necessary, all notices essential for safety when using the device must be affixed (note: this notice can only be the specific working of the ATEX text). These notices are described in detail under section 27 (Marking) in EN 50014. The most important information appears in the following table.

A permanently legible marking must contain, in addition to the manufacturer's name or trade-mark and type code, the following information:

Marking also includes issuing of a test certificate and naming the test location and certificate number.

Ex EEx de II C T6

- the EEx symbol
- the abbreviation of the ignition protection class used
- the symbol for the group of electrical equipment
- the symbol for the temperature class or the highest surface temperature in °C (for group II)

Marking also includes issuing of a test certificate and naming the test location and certificate number.

Identification of electrical equipment with certificate of conformity of an EC test location

E: built to European standard

Ex: explosion-protected equipment

Ignition protection type used

o: oil enclosure
p: pressurising system
q: sand enclosure
d: flameproof enclosure
e: increased safety
i: intrinsic safety
m: cast enclosure
SYST: intrinsically safe systems
n: non incendive

All ignition protection classes used for a piece of equipment must be specified after the main ignition protection class.
In the example above:
Main ignition protection class "d"
Secondary ignition protection class "e"

Range of application

I: mines susceptible to firedamp
II: all potentially explosive atmospheres exceptmines susceptible to firedamp

Sub-division of group II into IIA, IIB, IIC only for

flameproof enclosure "d"
Maximum permitted gap
A = > 0.9 mm
B = > 0.5 mm...0.9 mm
C = < 0.5 mm

Intrinsic safety "i"
Minimum ignition current ratio MIC
Ratio index related to methane

MIC
A = > 0.8
B = 0.45 ... 0.8
C = < 0.45

Temperature class	Max. surface temperature [°C]	Ignition temperature of flammable materials [°C]
T1	450	> 450
T2	300	> 300
T3	200	> 200
T4	135	> 135
T5	100	> 100
T6	85	> 85

at an ambient temperature range outside (-20 °C ... +40 °C), additional marking with T_a or T_{amb}.

Table 4.4 Marking of electrical equipment

Attention

The sub-division of explosion group II into IIA, IIB, IIC also applies to equipment of ignition protection class "n" (EN 50021, ...nC, ...nL), "o" and "m".

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A summary of older variant identifications appears in the appendix of the manual.

Different device markings will be explained using two examples. It should be noted that special markings are specified in DIN EN 50284 under section 6 for some ignition protection classes in reference to equipment of category 1.

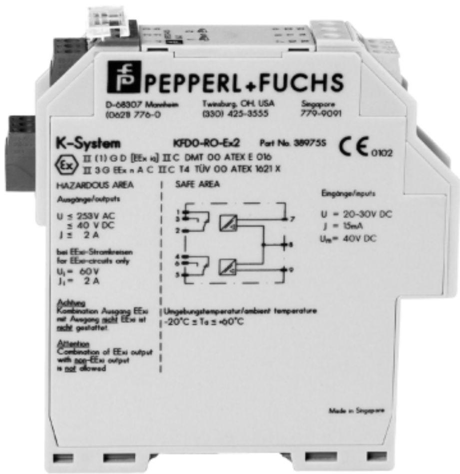

Figure 4.6 Related intrinsically safe equipment in ignition protection classes "i" and "n"

Example 1 Why can a device have two certificates and markings?

II (1) G D [EEx ia] IIC DMT 00 ATEX E 016
II 3 G EEx n A C IIC T4 TÜV 00 ATEX 1621 X

The character Ex specifically identifies the explosion protection class.

The first line **II (1) G D [EEx ia] IIC DMT 00 ATEX E 016** means:

II	Device group II	Use in non-firedamp explosive areas
()		Only part of the device meets requirements of the category
1	Category 1	Can be used in Zone 0 and/or 20
G	Gas	Can be used in/for areas with flammable gases
D	Dust	Can be used in/for areas with flammable dust
[...]		Related equipment of an intrinsically safe circuit; cannot be used in explosive environments without additional ignition protection classes (temperature class specification lacking)
EEx		Explosion protection type defined in specific European standards (for example EN 50020)
I	intrinsically safe	intrinsic safety ignition protection class
a	Protection level ia	Two-fault safety
IIC	Equipment group sub-division	Very low level of power provided (including in the event of failure)
DMT	Designated centre	that issued the EC Declaration of conformity (Gesellschaft für Forschung und Prüfung mbH [Research and Testing Organisation Ltd.])
00		Test year 2000
ATEX		In conformity with Directive 94/9/ EC (ATEX 95)
E 016		Test certificate number

The device in question is related equipment that cannot be used in the hazardous area, but an intrinsically safe circuit is available with very low power for Zone 0/20 (gas and dust). Tested by DMT in 2000.

Since the device in question is related equipment with an intrinsically safe circuit for Zones 0/20/1/21, it must be tested by a designated location (requirement of Directive 94/9/EC). This approval is thus an EC declaration of conformity.

Let us consider now the second line:

II 3 G EEx n A C IIC T4 TÜV 00 ATEX 1621 X:

II	Device group II	Use in non-firedamp explosive areas
3	Category 3	Can be used in Zone 2
G	Gas	Can be used in/for areas with flammable gases
EEx		Explosion protection type defined in specific European standards (for example EN 50021)
n		Ignition protection class which ensures during normal operation and under specific abnormal conditions that the equipment is not capable of igniting an ambient potentially explosive atmosphere
A		Non-sparking equipment
C		Sparking equipment with contacts protected in a suitable manner
IIC	Equipment sub-division	Very low level of power provided (including in the event of fault)
T4	Temperature class	Maximum surface temperature of the equipment in accordance with temperature class T4 (135 °C)
TÜV	Technical Monitoring Association	The designated center that issued the conformity information
00		Test year 2000
ATEX		In conformity with Directive 94/9/ EC (ATEX 95)
1621		Test certificate number
X	Special requirements	Special conditions included in the conformity information for safe usage that must be observed

Instead of the requirement for "X" marking, the equipment can also be given a warning to serve as marking.

This is a piece of equipment that can be used in Zone 2. Its energy, which is released under defined conditions, corresponds to the requirements of device group IIC. Its explosion protection type is "non-sparking or sparking with specially protected contacts". It was tested by TÜV in 2000. Special conditions that are recorded on the certificate must be taken into consideration.

Since this is equipment for Zone 2, it can be placed on the market with a statement of conformity issued by a manufacturer or a designated location. Devices for use in Zones 2 or 22 do not require any EC type examination test. Conformity with the requirements of EN 50021 is confirmed by this statement of conformity.

These two certificates have a completely different operational range. They are listed and identified on the device separately.

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Figure 4.7 Level control sensor for Zones 0 and 1 as well as 20 and 21

Example 2 Why can a field device have two markings?

EC declaration of conformity DMT 99 ATEX E 004

II 1/2G EEx d IIC T6/T5/T4/T3

II 1/2D IP 65 T202 °C/222 °C/242 °C/312 °C

The character Ex specifically identifies the explosion protection type.

The first line **II 1/2G EEx d IIC T6/T5/T4/T3** means:

II	Device group II	Use in non-firedamp explosive areas
1/2	Category 1/2	Wall-mounted equipment for the hazardous area with category 1 requirements
G	Gas	Can be used in/for areas with flammable gases
EEx		Explosion protection type defined in specific European standards (for example EN 50020)
d	Flameproof	Ignition protection class "flameproof enclosure"
IIC	Equipment sub-division	Very low level of power provided (including in the event of failure)
T_i	Temperature class T6/T5/T4/T3	Assignment of gases to temperature class depending on the maximum medium temperature.
		Page 2 of the EC Declaration of conformity specifies what temperatures gases may assume as a function of their assignment to temperature classes.
DMT	Designated centre	that issued the EC Declaration of conformity (Gesellschaft für Forschung und Prüfung mbH [Research and Testing Organisation Ltd.])
99		Test year 1999
ATEX		In conformity with Directive 94/9/ EC (ATEX 95)
E 016		Test certificate number

The device in question is explosion-protected equipment protected by a flameproof enclosure.

The vibration fork moves in Zone 0 and corresponds to category 1. The sensor head, which is located outside of Zone 0, corresponds to category 2. At medium temperatures that exceed the normal ambient temperature of 40 °C, there is a modified assignment of gases to temperature classes.

The second line **II 1/2D IP 65 T 202 °C /222 °C /242 °C /312 °C** means:

II	Device group II	Use in non-firedamp explosive areas
1/2	Category 1/2	Wall-mounted equipment for the hazardous area with category 1 requirements
D	Dust	It is thus established in/for areas with flammable types of dust that can be used with indication of 1/2D, that the vibration fork leads to Zone 20 (category 1), that it is mounted in the separating wall to Zone 21, and that the sensor head meets the requirements of Zone 21 (category 2).
IP	IP code	IP 6X means "dust-proof housing", which prevents dust from entering in visible quantities (requirement for use in Zone 20 and 21)
T_{xyz}		Specification of maximum surface temperature

The ⟨Ex⟩ identifier placed before the two markings is the specific identification of the explosion protection type. It indicates by way of a concrete example that the device has been designed and tested for use in explosive dust atmospheres.

In addition to the information in line 1, the test was based on conformity with EN 50281-1-1 Electrical equipment with protection by housing – construction and testing.

In contrast to use in explosive gas atmospheres (sub-division into temperature classes), for use in an explosive dust atmosphere, only the maximum surface temperature of the housing as measured in a test performed at an ambient temperature of 40 °C without a layer of accumulated dust is specified (in a specific case 202 °C). Correspondingly higher surface temperatures were determined at higher medium temperatures.

A temperature limitation in accordance with EN 50281-1-2 (Electrical equipment with protection by housing, selection, set-up and maintenance) applies to the user.

If dust clouds are present, the specified surface temperature T_{xyz} must not exceed two thirds of the ignition temperature of the dust/air mixture in question.

If accumulations of dust are present, the surface temperature must be reduced depending on the smoulder temperature of the layer of dust by at least 75 K (see section 6 of EN 50281-1-2).

Summary: This vibration fork sensor is approved for gas and dust explosion protection. Special attention must be paid to determining the surface temperature for use in explosive dust atmospheres, since there is no sub-division of temperature classes for different types of dust and a distinction must be made based on dust clouds and layers of dust.

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4.4 Electrical equipment in ignition protection class "Intrinsic safety"

4.4.1 Remarks on the definition of the intrinsically circuit

It follows from the definition of ignition protection classes specified under 4.2.5 that this ignition protection class always considers an intrinsically safe circuit to which intrinsically safe equipment, related equipment and the interface cables belong. European standard DIN EN 50020 defines the design conditions for equipment, while DIN EN 60079-14 contains "additional requirements for the Intrinsic Safety ignition protection class" in section 12, including specifications for cables and leads and how they must be installed. Since the intrinsic safety of a circuit can be very negatively effected by the installation, this topic will be discussed in detail elsewhere.

The following applies to each intrinsically safe circuit:

1. An intrinsically safe circuit consists of at least the following components:
   - Intrinsically safe electrical equipment (all internal circuits are intrinsically safe)
   - Related electrical equipment (not all, but at least one internal circuit is intrinsically safe)
   - Interface cable
2. Limiting the output excludes the possibility of a thermal effect. The output is either limited directly or it is limited indirectly by the open circuit voltage or the short circuit current.
3. The term spark includes both opening and closing sparks.
4. In the case of opening sparking (line is broken or opening of a mechanical contact) additional energy that was stored in the total inductance of the intrinsically safe circuit is liberated ($W = ½ LI^2$).
5. In the case of closing sparking (short circuit or closing of a mechanical contact) additional energy that was stored in the total capacitance of the intrinsically safe circuit is liberated ($W = ½ CU^2$).
6. Energy limiting by limiting dissipated power and energy storage (total inductance and total capacitance) of the intrinsically safe circuit is the basis in terms of circuitry of the Intrinsic Safety ignition protection method.
7. The basic circuit for limiting dissipated power includes
   - A resistor for limiting the short circuit current
   - A parallel circuit of Zener diodes for limiting the open circuit voltage
   - A fuse to protect the Zener diodes from overload

DIN EN 60079-14 notes (under 5.2.1 equipment for use in Zone 0 that *"electrical equipment" can be used in Zone 0 if it meets the requirements of IEC 60079-11 (category "ia"– Intrinsic Safety) and .... other requirements.* The IEC 60079-11 corresponds to DIN EN 50020.

This meets the determining criterion for subdivision into device categories, which requires in appendix I of ATEX 95 for category 1 that the necessary safety is ensured if 2 independent faults occur.

Note

To separate the term "Category" according to ATEX 95 in terms of devices from the term "Category" as it relates to intrinsic safety in accordance with DIN EN 50020, the term "protection level" is used below in conjunction with intrinsic safety, as is required in the revision of DIN EN 50020. [2]

Devices of device category 1 in the Intrinsic Safety ignition protection class must have protection level ia. Regardless of whether they have intrinsically safe or related electrical equipment, they must also be protected from two faults.

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A fault is defined as a component fault or a defective connection between two components on which the intrinsic safety of the circuit depends.

There will be no discussion of countable or uncountable faults at this point.

Using parts or modules that are not susceptible to interference achieves a high level of safety and also makes it easier to evaluate faults.

If the prescribed clearances and leakage paths are observed, they must also be treated as not susceptible to interference (see also requirements for setting up).

The required distances for terminal blocks are:

Minimum distance (mm)	between **terminal block** of intrinsically safe circuits and ...
50	non-intrinsically safe circuits
6	of other intrinsically safe circuits
3	grounded metal parts

Table 4.5 Minimum distance between terminal block

4.4.2 Protection level "ia" and "ib"

The definition of protection levels "ia" and "ib" is (see 5.2 and 5.3 DIN EN 50020):

Protection level "ia": When voltages U_m and U_i are applied, intrinsically safe currents in electrical equipment of protection level "ia" are not capable of causing ignition in any of the following cases:

- In operation without interference and with the uncountable faults that result in the most unfavourable condition present
- In operation without interference and with one countable fault present in addition to the uncountable faults that result in the most unfavourable condition present;
- In operation without interference and with two countable faults present in addition to the uncountable faults that result in the most unfavourable condition present;

Protection level "ib": When voltages U_m and U_i are applied, intrinsically safe currents in electrical equipment of protection level "ib" are not capable of causing ignition in any of the following cases:

- In operation without interference and with the uncountable faults that result in the most unfavourable condition present
- In operation without interference and with one countable fault present in addition to the uncountable faults that result in the most unfavourable condition present. [2]

Attention

In Draft E DIN IEC 60079-11 (VDE 0170/0171, part 7): 2004-12, protection level "ic" is described under 5.4 as follows:

When voltages U_m and U_i are applied, the intrinsically safe currents in the electrical equipment of protection level "ic" must not be capable of causing an ignition in operation with no interference and in the presence of the innumerable errors that result in unfavourable conditions.

It may thus be assumed that protection level "ic" is assigned to Zone 2 equipment.

4.4.3 Safety barriers

Safety barriers form the interface between intrinsically safe and non-intrinsically safe circuits. They transmit electrical signals bidirectionally and limit the electrical energy that is transferred from the safe area into the hazardous area in normal operation and in the event of a failure.

The purpose of the barrier is to limit the current and voltage in intrinsically safe circuits in the following failure cases:

- Case 1: Voltage too high on the non-intrinsically safe side
- Case 2: Short circuit on the intrinsically safe side

The working principle of the safety barrier is based on the fact that during normal operation the voltage applied between Terminals 7 and 8 is always less than the reverse breakdown voltage U_Z of the Zener diodes. Thus the Zener diodes are blocked.

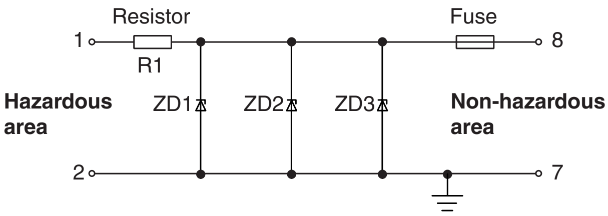

Figure 4.8 Circuit diagram illustrating the working principle of a Zener barrier

In failure case 1, the Zener diodes are conducting, the fuse is tripped and protects the Zener diode from overload. This prevents an impermissibly high amount of energy from entering the intrinsically safe circuit. In accordance with section 9.2 of EN 50020, the entire safety barrier must form a single unit to prevent components on which the safety depends from being replaced. Since the fuse is also one of these components, failure case 1 results in an irreparable fault.

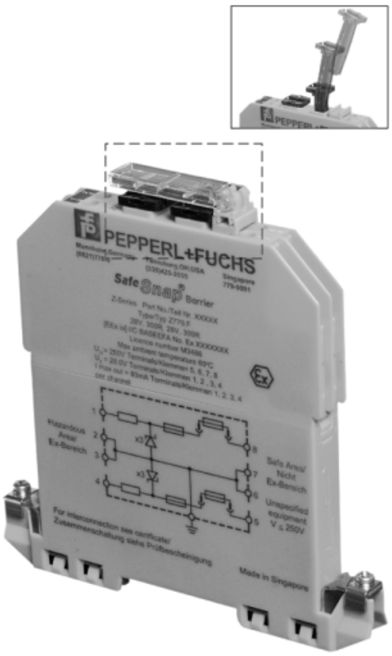

Figure 4.9 Zener barriers with replaceable fuse

Adding a replaceable fuse in front of the integrated fuse protects the device from being destroyed if any faults occur while the system is placed in service. It is always ensured that the external is tripped before the internal fuse, which is not accessible. Special fuse types designed for safety barriers should be used for this purpose.

In failure case 2, the fuse is tripped or the current is limited to

$I_k = U_z/R_1$

A distinction is made between safety barriers with and without galvanic separation.

Safety barriers without galvanic separation can be used for separation between intrinsically safe and non-intrinsically safe circuit. These modules are usually called **Zener barriers**.

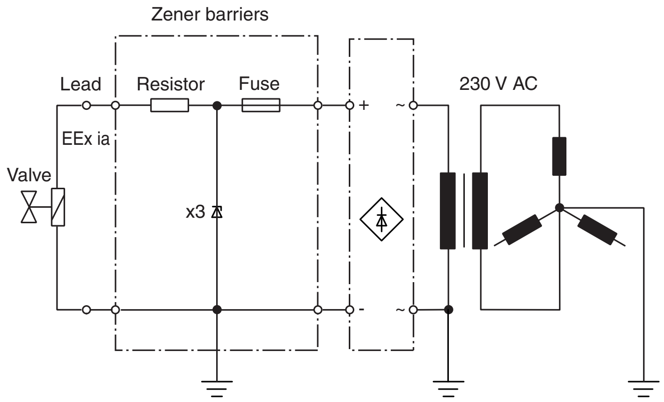

Figure 4.10 Circuit of a valve control circuit with power supply Zener barrier and intrinsically safe valve control circuit.

Only equipment with a maximum voltage in the event of a failure that is no higher than the value that is permissible for the safety barrier can be connected on the non-intrinsically safe side of the safety barrier (U_{max} on the declaration of conformity and on the manufacturer's rating plate).

The maximum voltage in the event of a malfunction is the power supply voltage of the connected equipment. Because of this, barriers are typically designed for 253 V AC.

Since Zener barriers are operated with polarity, positive and negative potential must be differentiated for safety barriers. In addition, there are also devices for alternating potential.

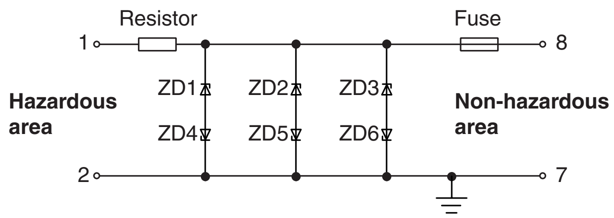

Figure 4.11 Zener barriers for alternating polarity

"Evaluation barriers" are also available. They allow current only from the hazardous area. This is achieved by series switching of diodes in the input circuit.

Since there is galvanic separation between the intrinsically safe and non-intrinsically safe circuit, impermissibly high values (against ground) can occur in spite of limiting the voltage and current in the measurement circuit. Because of this, additional measures are required during installation (see installation or setup requirements). The potential equalisation required in this case creates a reliable ground and is permitted because it is required for functional reasons.

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If galvanic separation is added to the safety barrier described above between the intrinsically safe and non-intrinsically safe circuit, the result is additional advantages for relatively minor installation costs:

- A ground connection of intrinsically safe equipment is permitted for operation in the field since an equalisation current can only flow at one point with grounding
- There are no faults for measurements resulting from ground potentials
- The intrinsically safe circuit and evaluation circuit can be at a different potential
- There are no longitudinal resistances interfering with functionality

In accordance with section 12.3 of EN 60079-14, related equipment with galvanic separation between the intrinsically safe and non-intrinsically safe circuits are preferred for systems in Zone 0.

Galvanic separation by the transfer unit must meet the requirements of EN 50020, (i. e. leakage/clearance paths, protected for voltages up to 2500 V, etc.) must be observed.

These requirements also ensure galvanic separation in the event of a failure, the full supply voltage is applied to the transfer unit.

Figure 4.12 Switch amplifier (DIN-Rail housing)

4.4.4 Simple electrical equipment

In accordance with 5.4 of DIN EN 50020, the following should be considered simple pieces of electrical equipment:

- Passive components, for example switches, distributor boxes, resistors and simple semi-conductor components.
- Energy storage devices with precisely specified rating values, for example capacitors or coils, whose values must be taken into consideration when determining the overall safety of the system.
- Energy sources, for example thermocouples and photoelectric cells that do not generate any more than 1.5 V, 100 mA and 25 mW. All coils and capacitor in these energy sources must be considered as under b).

Simple electrical equipment must meet all applicable requirements of this standard, but it is not considered a potential ignition source that could cause an explosion, and does not need to be marked according to section 12 of EN 50020. [2]

4.4.5 Electrical limit values of intrinsically safe circuits, explosion limit curves

Electrical limit values of intrinsically safe circuits

The Intrinsic Safety ignition protection class is based on limiting energy in the intrinsically safe circuit, i. e. it is based on limiting

- The short circuit current, open circuit voltage and power
- The total inductance of the circuit depending on the short circuit current
- The total capacitance of the circuit depending on the open circuit voltage

The electrical limit values of these circuits including the output value must always be specified on declarations of conformity and on the equipment.

The following limit values are important to be able to demonstrate the intrinsic safety of a circuit [2]:

Related electrical equipment:

- U_o, I_o, P_o
- L_o (maximum inductance that can be connected)
- C_o (maximum capacitance that can be connected)

Intrinsically safe electrical equipment:

- U_i, I_i, P_i
- L_i (maximum internal inductance)
- C_i (maximum internal capacitance)

Explosion limit curves [2]

The electrical limit values of intrinsically safe circuits are determined by the authorised test locations. Explosion limit curves are used for this purpose. They are illustrated in EN 50020 in Fig. A1 to A6. These explosion limit curves represent the following relationships:

- Ohm circuit I_o = f (U_o)
- Inductive circuit L_o = f (I_o)
- Capacitive circuit C_o = f (U_o)

The explosion limit curves illustrate the higher levels of ignition power for the ohm and inductive circuit for explosion group I and the lowest levels of ignition power for group IIC.

The explosion curves do not include the safety factor of 1.5 required in accordance with EN 50020 section for protection levels ia and ib. The safety factor is worked into the tables in EN 50020, which contain explosion limit curves in table format. This safety factor is taken into consideration in the specification of the electrical limiting values in the certification documents and on the equipment.

In considering stored energy in the intrinsically safe circuit, it should be noted that the explosion limit curves reflect only the ignition behaviour of purely inductive or purely capacative circuits (see replacement circuit diagram in the representation of the explosion limit curve in question). This problem will be discussed in greater detail in connection with the proof of intrinsic safety.

The appendix to EN 50020, which has the force of a standard, requires that three basic criteria be met for the intrinsically safe circuit:

- The circuit must be adequately separated from other circuits.
- The categorisation of temperature classes for intrinsically safe electrical equipment must be made in accordance with EN 50020, section 6.2 and EN 50014, section 5. This will ensure that no ignition is caused by hot surfaces. The sub-division into temperature classes do not apply to the related equipment.
- There must be no spark ignition if the circuit for the category in question (see section 5) and the classification of electrical equipment in groups (see section 4) is tested in accordance with section 10.

Attention

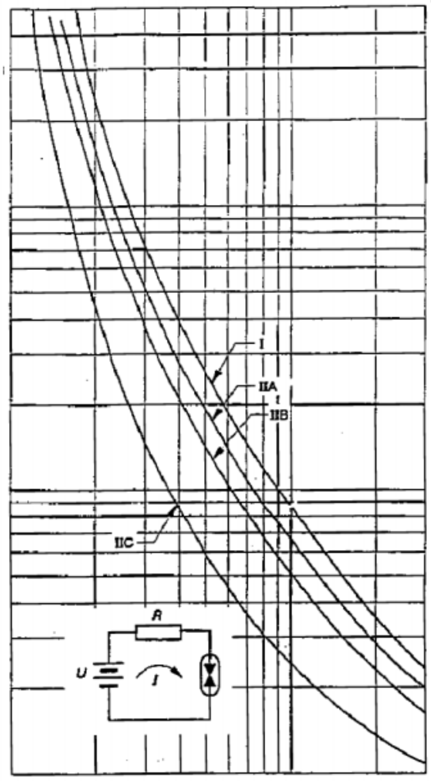
Criterion a) can be satisfied by appropriate leakage paths and clearances and by using parts of transformers or current limiting resistors, for example, according to section 8 (components, modules and connections that are not susceptible to interference).

Criterion b) can be satisfied by estimating the maximum surface temperature of components based on a knowledge of their thermal behaviour and the maximum output to which they may be exposed under the corresponding failure conditions.

Criterion c) can be satisfied by theoretical evaluations. Information is required in reference to voltage, current and circuit parameters such as capacitance and inductance at the ignition limits. The circuit can thus be evaluated as intrinsically safe in reference to spark ignition. [2]

It is the responsibility of the installer or operator to provide proof of intrinsic safety. This proof is a compulsory part of the explosion protection document.

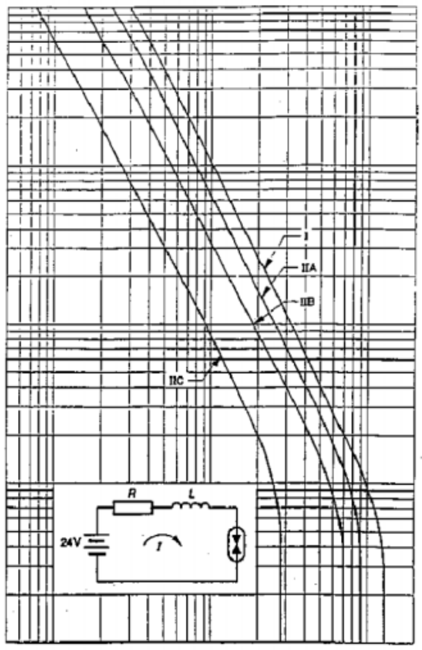
Minimum ignition current I (A)



Source voltage U (V)

Fig. A.1: Resistive circuits [2]

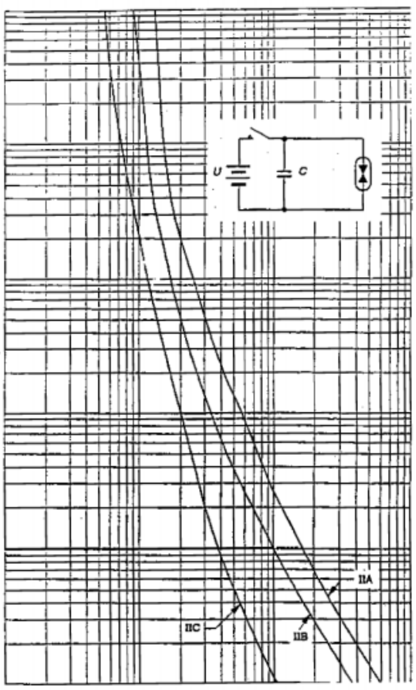
Inductance L (H)



Minimum ignition current I (A)

Note:
The test voltage of the circuit is 24 V
Fig. A.4: Inductive circuit [2]

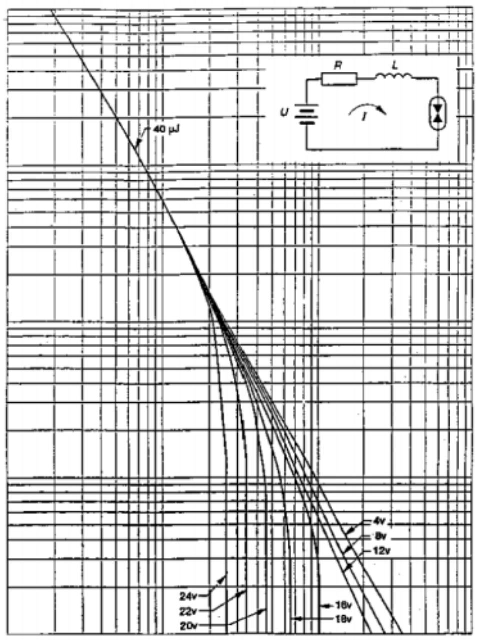
Capacitance C I (µF)



Minimum ignition voltage U (V)

Fig. A.3: Capacitive circuit in group II [2]

Inductance L (H)



Minimum ignition voltage I (A)

Note 1:
The curves correspond to the given values of voltage U_o in the circuit.

Note 2:
The 40 µJ energy level relates to the common linear portion of the curves.
Fig. A.6: Inductive current circuit in group II [2]

Figure 4.13 Explosion limit curves for resistive and capacitive circuits

4.5 References

Note

*The definition of the ignition protection class was taken from the corresponding European standard DIN EN 500** without citing the full details of the source*

[1] Cert. Eng. Erich Lienenklaus presentation "Introduction to electrical explosion protection" Haus der Technik 2002

[2] DIN EN50020: 2002 Electrical equipment for potentially explosive atmospheres, intrinsic safety "i"

[3] Cert. Eng. (HF) Wolfgang Gohm Explosion protection in MSR technology, introduction for practical use

[4] Cert. Eng. Thorsten Arnhold: Standards work on the theme of explosion protection of electrical apparatus

[5] Cert. Eng. Thorsten Arnhold: Explosion-protected switching devices and switchgear/control gear, atp 48 (2006) Vol. 5

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5 Installation requirements

DIN EN 60079-14 VDE 0165, part 1 and DIN EN 50281-1-2 VDE 0165, part 2

5.1 Preliminary remarks

When installing electrical systems in hazardous areas, in addition to the in general requirements of DIN VDE 0100, DIN VDE 0101, DIN VDE 0106, DIN VDE 0800, etc., further requirements must be observed.

For hazardous areas in underground mining construction (explosion group I), DIN VDE 0118 and the mining regulations apply in addition. However, these special requirements that must be observed for installation in these areas will not be further discussed at this point.

A generally applicable requirement for installations in all other hazardous areas is the Industrial Safety Regulation (BetrSichV) of Sept. 27, 2002. Appendix 4 of the Industrial Safety Regulation specifies the criteria for selecting equipment.

Concrete specifications for installing electrical systems in potentially explosive gas atmospheres are included in DIN EN 60079-14 (VDE 0165, part 1) "Electrical equipment for potentially explosive gas atmospheres, part 14: Electrical systems in potentially explosive atmospheres (except for mining construction)".

If there are areas that are endangered by the risk of dust explosion the requirements of DIN EN 61241-14 (VDE 0165-2) "Electrical apparatus for use in areas with combustible dust" – part 14: Selection and installation, must be taken into account. This standard has been valid since June 1, 2005 and replaces in part old standards, e. g. DIN EN 50281-1-2, which are to be withdrawn by September 1, 2007.

The most important requirements for installation in potentially explosive gas and dust atmospheres are described below. No claim is made that this is a complete list. Because of the special risk involved for installation in potentially explosive atmospheres, planners, installers, operators or testers of electrical systems in these areas must be sufficiently concerned with applicable standards.

Work in potentially explosive atmospheres must only be performed by personnel with appropriate professional training. Of course this applies particularly and to a special degree when setting up systems in potentially explosive atmospheres. When installing electrical systems, in addition to in general requirements (journeyman qualification letter), no additional proof of qualification is required for electrical specialists who are involved. However, electrical specialists who set up electrical systems in potentially explosive atmospheres are required to become informed about special requirements for installation in these areas since ultimately they can always be made responsible if their work is not performed properly.

For example, just as persons setting up electrical systems in hospitals, sales locations, meeting locations, etc. must become informed about special features to be taken into account there, persons setting up electrical systems in potentially explosive atmospheres are required to observe additional requirements in effect there in the currently valid version.

The additional requirements for installations of ignition protection class "i" intrinsic safety (section 12 in DIN EN 60079-14) will be discussed in greater detail elsewhere.

The draft of DIN IEC 60079-14 (VDE 0165-1) has been available since January 2006 and has been extensively reworked in respect of the currently valid standard, with the introduction of new aspects. The (apparatus)/Equipment Protection Levels (EPL) defined in this draft are already contained in the valid standards on electrical and non-electrical apparatus. The author of this manual regards this draft standard in the widest sense as the state of the art and for this reason it will be dealt with in some detail.

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5.2 General requirements

Installation of electrical equipment in potentially explosive atmospheres should be limited to the bare essentials. Since all electrical equipment, even if it is designed to be protected from explosion, can become a source of ignition under special circumstances (for example in the case of mechanical damage), electrical equipment should be installed outside the potentially explosive atmosphere wherever possible.

However, if it is not possible to avoid installing electrical equipment in potentially explosive atmospheres, the equipment should be located in the area with the lowest risk of explosion if at all possible.

The following information must be present to ensure correct choice of and proper installation of equipment:

- Documents for zone classification
- For potentially explosive gas environments: ignition temperature and explosion group of the gas/air mixture
- For potentially explosive dust environments: ignition temperature of the dust/air mixture and smoulder temperature of the accumulated dust
- Instructions for setting up and connecting equipment (insofar as is required)
- Documents for electrical equipment with special requirements, for example equipment with certification numbers that have the additional letter "X"
- System description for an intrinsically safe system (proof of intrinsic safety)
- Manufacturer's declarations/declarations of qualified persons (or authorized persons).

Additional information regarding any mechanical, thermal and chemical influences that may be present, special demands or loads due to water and foreign objects and in particular due to the ambient temperature is required for installation in potentially explosive atmospheres. This applies both for potentially explosive gas atmospheres and potentially explosive dust atmospheres.

The documents and information listed for this case must be considered as absolutely essential for a proper installation. They must be determined and taken into consideration beginning with the planning phase for systems and can then become part of the explosion protection document to be created in accordance with the Industrial Safety Regulation.

The recommended content of a dossier of evidence is listed in section 4.6 of IEC 61241-14, which names all the currently required information for plant documentation and which reads almost like a list of contents of an explosion protection document.

5.3 General information on selecting electrical equipment

Since July 1, 2003 in accordance with the ExVO (Explosion Protection Directive – 11.GSGV) only devices, protection systems and components that meet the requirements of the European Parliament and Council Directive 94/9/EC of March 23 1994 (ATEX 95) may be placed in circulation for use in potentially explosive atmospheres.

The Industrial Safety Regulation also requires that equipment intended for use in potentially explosive atmospheres and that is provided to those using it for the first time after July 1, 2003 must meet the requirements of ATEX 95. This equipment also includes electrical equipment.

Appendix 4, section B of the Industrial Safety Regulation clearly defines the category for which requirements must be met in the respective zones.

In accordance with ExVO, § 7 until June 30, 2003 devices and protection systems meeting the requirements of previous law (more precisely the law in effect on March 24, 1994) could be placed in circulation. This equipment can also continue to be operated after this date.

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It should not go unmentioned in this context that ExVO applies to all technical equipment for work in commercial and private applications (and thus to non-electrical devices as well). However, it applies to devices only if they are used in whole or as part of a system in a potentially explosive atmosphere and if they themselves could become an ignition source.

The Industrial Safety Regulation as well is not limited only to electrical equipment or electrical systems, as was ElexV, which was valid until December 31, 2002.

Explosion groups

To select explosion-protected electrical equipment, a distinction must first be made between two groups of equipment:

Group I:	Electrical equipment for firedamp protected mining construction (methane)
Group II:	Electrical equipment for all other potentially explosive atmospheres

Explosion group I will not be discussed in any greater detail in this context. In Explosion group II, a sub-division is made into potential gas explosion hazardous areas and potential dust explosion hazardous areas.

5.4 Selecting equipment for potential gas explosion hazardous areas

5.4.1 Equipment for use in Zone 0

Zone 0 allows for use of both electrical and non-electrical devices that are or that contain potential ignition sources as well as protection systems (for example permanent fireproof fittings, flame locks, etc.) if they are identified as follows:

Ex II 1 G

This marking is compulsory for all equipment for use in Zone 0 if the equipment was placed in circulation after June 30, 2003.

Explosion protection for electrical equipment for use in Zone 0 is generally ensured by ignition protection method for intrinsic safety "EEx ia". It is also possible to use the special cast enclosure (ignition protection type "ma") of two independent technical protection measures (two mutually independent ignition protection types) or an ignition protection type with a separating element (see also DIN EN 50284).

In addition to the type examination certificate number of a designated location (notified body) and the ignition protection class, the explosion group and temperature class must also be specified on the electrical equipment.

An "X" after the certificate number refers to "special conditions" that must be observed for installation of the equipment. These conditions are described on the test certificate and in the instruction manual.

5.4.2 Equipment for use in Zone 1

Zone 1 allows for use of both electrical and non-electrical devices that are or that contain potential ignition sources as well as protection systems (for example permanent fireproof fittings, flame locks, etc.) if they are identified as follows:

Ex II 2 G

This marking is compulsory for all equipment for use in Zone 1 if the equipment was placed in circulation after June 30, 2003.

In addition, equipment approved for Zone 0 can also be used in Zone 1.

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Explosion protection for electrical equipment in Zone 1 is ensured by one or more of the following ignition protection classes:

• Oil enclosure	Marking: EEx o Building standard: DIN EN 50015
• Pressurising systems	Marking: EEx px, py, pz Building standard: DIN EN 50016 or DIN EN 60079-2
• Sand enclosure	Marking: EEx q Building standard: DIN EN 50017
• Flameproof enclosure	Marking: EEx d or Ex d Building standard: DIN EN 50018 or DIN EN 60079-1
• Increased safety	Marking: EEx e or Ex e Building standard: DIN EN 50019 or DIN EN 60079-7
• Intrinsic safety	Marking: EEx ia or EEx ib Building standard: DIN EN 50020
• Cast enclosure	Marking: EEx m or Ex ma or Ex mb Building standard: DIN EN 50028 or DIN EN 60079-18

The building standards for electrical equipment specified here for hazardous areas with the danger of gas explosions must be applied in addition to DIN EN 50014 or DIN EN 60079-0, in which the general requirements are described.

In addition to these ignition protection types, there is another protection type for equipment that does not fit any of the protection types listed above, ignition protection type "Special Protection" identified by "Ex s".

In addition to the type examination certificate number of a designated location (notified body) and the ignition protection class, the explosion group and temperature class must also be specified on the electrical equipment.

An "X" after the certificate number refers to "special conditions" that must be observed for installation of the equipment. These conditions are described on the test certificate and in the instruction manual.

5.4.3 Equipment for use in Zone 2

Zone 2 allows for use of both electrical and non-electrical devices that are or that contain potential ignition sources as well as protection systems (for example permanent fireproof fittings, flame locks, etc.) if they are identified as follows:

Ex II 3 G

This marking is compulsory for all equipment for use in Zone 2 if the equipment was placed in circulation after June 30, 2003.

In addition, equipment approved for Zones 0 and 1 can also be used in Zone 2.

DIN EN 60079-14 (VDE 0165, part 1) section 5.2.3 further applies to electrical equipment for use in Zone 2 in that it can only be used if it

- Is specially designed for Zone 2 (for example ignition protection class "n" in accordance with DIN EN 50021), or
- Is deemed suitable for use in Zone 2 by a person suitable to make such a decision. Requirements for this person and the check are described in DIN EN 60079-14 (VDE 0165, part 1).

The explosion group, temperature class and, if ignition protection class "n" is used, the specially applied ignition protection class (nA, nC, nL, nR or nZ) as well must be indicated on the electrical equipment.

An "X" after the certificate number (if it is present) or after the identification of the ignition protection class refers to "special condition" that must be observed for installation of equipment. These conditions are described on the test certificate (if there is one) and in the instruction manual.

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5.4.4 Special arrangements in accordance with ExVO, §4 Paragraph 5

If it is not possible for specific reasons to perform the process described in EC Directive 94/9/EC (ATEX 95) for placing a device or a protection system in circulation, Paragraph 5 of §4 of the Explosion Protection Regulation allows a special option for placing such devices or protection systems in circulation.

This can be considered for devices, protection systems or equipment that is used in the area of research and development. Even if these are prototypes, it may not be economically feasible under certain circumstances, for manufacturers to perform a procedure to evaluate conformity in accordance with ATEX 95.

In addition, many types of electrical equipment of the pressurising systems "EEx p" ignition protection class can only be checked on site by the operator with a special arrangement, since often the entire system consisting of housing, pipe lines for infeed and output, etc. for these devices cannot be transported and therefore cannot be checked in the lab.

Application must be filed for use of a special arrangement with the responsible officials (generally the government office for work protection, in Germany StAfA or the commercial supervisory office).

Otherwise the process is still relatively unregulated. It is clear that in any case, a special arrangement of this type must meet the basic safety and health requirements of appendix II of ATEX 95.

According to the old law (§ 5 ElexV), special arrangements could be placed in circulation if a recognised expert as defined by §14 of the Device Safety Law had issued a corresponding test certificate. The is by no means the least reason why the responsible agency will also require the opinion of a competent checking centre for special arrangements in accordance with ExVO.

Provided the expert referred to above is not an expert according to the Device Safety Law, which will not be available until December 31, 2007 due to transitional regulations, agency officials will presumably require an opinion of an approved monitoring location (AML) in accordance with the Industrial Safety Regulation.

There is every reason to believe this, since the approved monitoring location also replaces the recognised expert in accordance with §14 GSG in reference to other checks.

5.4.5 Explosion groups

There is an additional sub-division for electrical equipment of group II for potentially explosive gas/air mixtures:

The ignition capability and ignition breakdown behaviour of a potentially explosive mixture are properties typical of a substance. Gases and vapours are subdivided into explosion groups. The criteria for sub-division are the maximum permitted gap and the minimum ignition current.

The maximum experimental safe gap (MESG) and minimum ignition current (MIC) are determined under precise experimental conditions for different gases.

The following list provides an overview of explosion groups with examples of gases and vapours:

Explosion group IIA: Acetone, ethane, ethyl acetate, ammoniac, benzole (pure), acetic acid, acetic anhydride, toluole, i-amyl acetate, n-butane, n-butyl alcohol, benzines, n-hexane, diesel fuel, acetic aldehyde, phenol

Explosion group IIB: Ethyl ether, ethylene, ethylene oxide, ethyl alcohol, hydrogen sulphide, city gas (illuminating gas)

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Explosion group IIC: Acetylene, carbon sulphide, hydrogen

The danger level of gases increases from Explosion group IIA to IIC. The requirements for electrical equipment for these explosion groups increase accordingly. Because of this the Explosion group for which electrical equipment is designed must be specified on it if the explosion protection depends on the maximum permitted gap (Ignition protection class EEx d) or the minimum ignition current (Ignition protection class EEx i).

Electrical equipment that is approved for IIC can also be used for all other explosion groups, while equipment for IIB can also be used for Explosion group IIA.

5.4.6 Temperature classifications

The ignition temperature of a flammable gases or flammable liquid is the lowest temperature at which the mixture susceptible to ignition can still be brought to explosion under the conditions specified according to DIN 51794.

This makes it possible to classify flammable gases and vapours into temperature classifications according to their capacity to ignite. The maximum surface temperature of a piece of electrical equipment must always be less than the ignition temperature of the gas or vapour/air mixture in which it is used.

Of course equipment the meets the requirements of a higher temperature class (for example) is also approved for applications for which a lower temperature class is required (for example T2 or T3).

The following list provides an overview of temperature classifications with examples of gases and vapours:

Temperature class T1

- Highest permissible surface temperature of the equipment: 450 °C
- Ignition temperatures of flammable materials: > 450 °C

Examples: Acetone, ethane, ethyl acetate, ammoniac, benzole (pure), acetic acid, toluole, phenol, city gas (illuminating gas), hydrogen

Temperature class T2

- Highest permissible surface temperature of the equipment: 300 °C
- Ignition temperatures of flammable materials: > 300 °C

Examples: Acetic anhydride, i-amylacetate, n-butyle alcohol, n-butane, ethylene, ethylene oxide, ethyl alcohol, acetylene

Temperature class T3

- Highest permissible surface temperature of the equipment: 200 °C
- Ignition temperatures of flammable materials: > 200 °C

Examples: Benzines, n-hexane, diesel fuel, hydrogen sulphide

Temperature class T4

- Highest permissible surface temperature of the equipment: 135 °C
- Ignition temperatures of flammable materials: > 135 °C

Examples: Acetic aldehyde, ethyl ether

Temperature class T5

- Highest permissible surface temperature of the equipment: 100 °C
- Ignition temperatures of flammable materials: > 100 °C

Examples: None

Temperature class T6

- Highest permissible surface temperature of the equipment: 85 °C
- Ignition temperatures of flammable materials: > 85 °C

Examples: carbon sulphide

For identifying data of additional substances, see: "Intrinsic safety ID numbers of combustible gases and vapours"; Nabert, K.; Schön, G.; 2nd expanded edition 1963 and "5th supplement to the system of tables" by Nabert, K. and Schön, G. (1980 edition); Schön, G.; Redeker, T.; Deutscher Eichverlag GmbH, Braunschweig

5.5 Installation of electrical systems in explosive gas atmospheres

5.5.1 Protective measures

Protective measures against direct contact with life parts no matter what the level of voltage (thus even for SELV safety extra low voltage and PELV protective extra low voltage) are always required. Exceptions can only apply to parts of intrinsically safe circuits.

The following protective measures could be used for protection with indirect contact in accordance with DIN VDE 0100, part 410:

- Protection by switching off in the
  - TN-S system (the TN-C system is not permitted in potentially explosive atmospheres)
  - TT system (only with RCD residual current device) and in the
  - IT system (only with isolation monitoring mechanism)
- SELV safety extra low voltage
- PELV protective extra low voltage (with safe separation)
- Safety separation

5.5.2 Potential equalisation

Potential equalisation is required in potentially explosive atmospheres to prevent sparks that could ignite. In TN, TT and IT systems, all bodies of electrical equipment and all parts capable of conducting extraneous currents must be connected to the potential equalisation system.

The connections and attachments must be protected against working themselves loose.

Parts capable of conducting currents that do not belong to the construction or installation of the system and for which there is no possibility of potential drag caused by error currents (for example door frames and window frames) as well as metallic housings of intrinsically safe equipment (unless it is required in the documentation for the equipment) do not need to be included in the potential equalisation.

Potential equalisation must meet the requirements of DIN VDE 0100, part 410 and part 540.

5.5.3 Lightning protection

The effects of lightning strikes must be limited to a level that is not dangerous. This includes protection against the effects caused by "direct" lightening strikes as well as protection against strikes that occur away from the building. Strikes that occur away from the building may result in risk of damage due to overvoltage.

Since VDE 0185 part 1 and 2 have been withdrawn and there is currently no standard for lightning protection systems, DIN VDE 0185, part 1 to part 4 should be observed when setting up lightning protection systems. E DIN VDE 0185, part 2 "Risk Management for Lightning Strike: Estimation of Risk of Damage for Physical Facilities" provides a concrete description of how to determine the need for lightning protection measures based on a hazard evaluation. DIN VDE 0100, part 443 must be observed for protective measures against overvoltage caused by lightning strikes away from the building.

In accordance with this part of DIN VDE 0100, a risk analysis must be performed to weight the issues of protection and consequences taking into account the probability of overvoltage occurring.

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5.5.4 Emergency stop and disconnecting

Mechanisms must be present outside the potentially explosive atmosphere to turn off the power supply of the potentially explosive atmosphere for emergency cases (emergency stop switch).

Electrical equipment that must continue to operate to prevent additional dangers (for example lights) must not be connected to the emergency shut-off system. Instead, it must be possible to turn it off in a separate circuit. In addition, mechanisms for disconnecting must be provided for each circuit or each circuit group to make it possible to disconnect all conductors carrying electricity including the neutral conductor.

5.5.5 Installation of electrical machines

A number of special requirements must be observed for installation of electrical machines in potentially explosive atmospheres.

In general, electrical machines must be protected against overload in addition to the damaging effects of ground fault and short circuits. The only exceptions are machines that can permanently conduct the start-up or short circuit current without heating up to impermissible levels.

The following must be used as overload safety mechanisms in accordance with DIN EN 60079-14 (VDE 0165, part 1), section 7:

- A current-dependent, time-delayed safety mechanism for monitoring all three phases, not adjusted higher than to the measurement current of the machine, which must engage at 1.2 times the set current within 2 hours and must not engage at 1.05 times the set current within 2 hours, or
- A mechanism for direct temperature monitoring by means of embedded temperature probes, or
- Another comparable mechanism.

In addition, measures must be taken so that a three-phase current motor cannot continue to be operated if one phase fails.

The safety mechanisms must be designed so that switching back on under failure conditions is prevented.

Additional requirements must be observed for electrical machines of ignition protection class "Increased safety Ex e". Overload protection for machines such as these must be designed so that not only is the motor current monitored, but a motor that has been stopped by a brake is also turned off within the time t_E specified on the rating plate.

The trigger current path characteristic of the safety mechanism in use must be available for this purpose. This current path characteristic indicates the trigger time as a function of the energising current ratio I_A/I_N, which is also indicated on the motor's rating plate. The trigger time determined based on the trigger current path characteristic of the safety mechanism must be less than time t_E.

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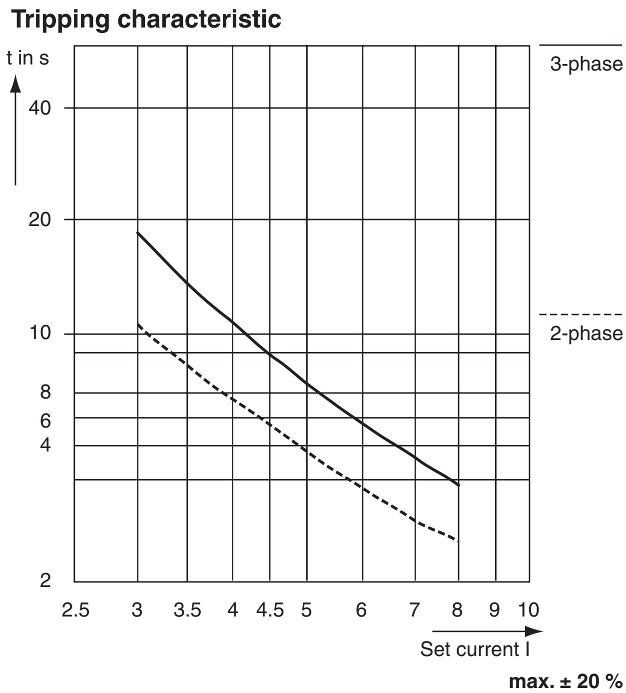

Figure 5.1 Trigger current path characteristic of a motor protection mechanism

The trigger times of protective mechanisms may deviate from manufacturer to manufacturer and between different designs for the same manufacturer. They may also differ sharply from each other for the different setting ranges of a given design. The special current path characteristic of the motor protection mechanism in use must therefore be available in each case.

It should also be noted that the trigger times t_E of a motor may vary for different temperature classes (for example T1: t_E = 16 s;T2: t_E = 16 s; T3: t_E = 15 s; T4: t_E = 8 s). The graphic shows the temperature behaviour of electrical machines and clearly illustrates the connection between the t_E time and increase in temperature.

If Ex-e motors will be used with devices for direct temperature monitoring (winding temperature probe), this must be specified in the motor documentation and specially tested and certified. The type of the embedded temperature probe or of the associated protective mechanism must be specified on the machine.

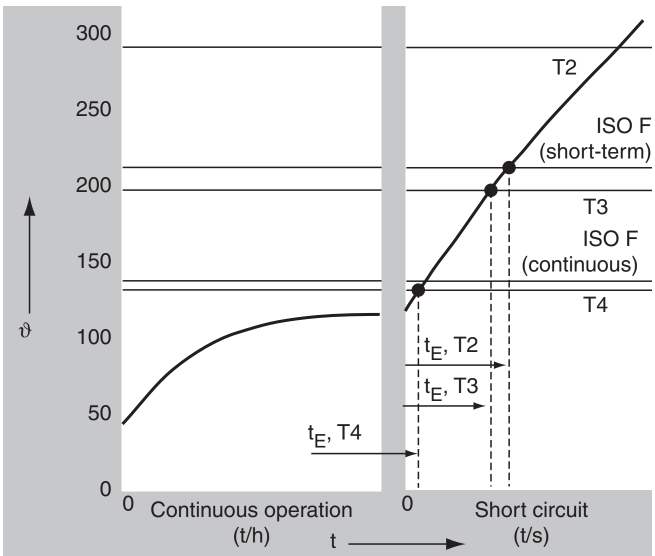

Figure 5.2 Heating up behaviour of electrical machines

The point of switching off for T2 is limited by ISO F. ISO F is the maximum temperature of the insulating varnish. Accordingly that is, the disconnection for T2 effected with 300 °C, but it is limited by the maximum temperature of the insulating varnish (temporary 210 °C or continuously 140 °C).

Motors of ignition protection class Ex e that are intended for operation at a variable frequency and voltage must be specially checked and certified for that purpose. The motor must be subjected to a type test together with the converter and the protection mechanism that is provided as one whole unit.

A type test of the converter, protective equipment and machine can also be performed for electrical machines of ignition protection type "flameproof enclosure: EEx d" if operation includes variable frequency and voltage.

There is no need for such a check for Ex d motors if a machine of this type is equipped with embedded temperature probe for direct temperature monitoring. The requirements of the protective mechanisms for limiting the surface temperature must be described in the documentation. The safety mechanism must turn the motor off.

It is clear from practical application that flameproof enclosure motors are used most frequently for electrical drives in potentially explosive atmospheres that will be operated with speed control.

Since the range of application of these motors is not limited to converters listed for use with them on the certificate provided they have embedded temperature probes and the operating conditions are specified in the documentation, they can be used in a much more versatile and flexible manner.

5.5.6 Electrical protection measures for motors

EN 60079-14 requires in section 7 "Electrical protection measures" [1]:

Rotating electrical machines must additionally be protected against overload, with the exception of motors, which are capable of continuously carrying the starting current at the rated voltage and rated frequency and generators, which can continuously carry the short-circuit current without an impermissible rise in temperature.The following must be used as overload protection devices:

- *A current-dependent, time delayed protection device for monitoring all three phases, not set higher than the rated current of the machine, which must respond at 1.2 times the set current within 2 h and must not have responded at 1.05 times the set current within 2 hours, or*
- *A device for the direct monitoring of temperature by means of an embedded temperature sensor, or*
- *Another device performing the same function.*

In addition, EN 60079-14 demands "e" – increased safety for the ignition protection category as thermal overload protection in paragraph 11.2.1:

In order to satisfy the requirements of section 7 the current-dependent time delayed overload protection devices must be such that not only the motor current is monitored, but also the stalled motor must be switched off within the time t_E stated on the rating plate. The current/time characteristics, which give the delay time of the overload relay or overload release as a function of the ratio of the starting current to the rated current, must be available to the operator.

These characteristics give the release time, from the cold condition at an ambient temperature of 20 °C and for a starting current ratio (I_A/I_N) of at least 3 to 8. The protection devices must maintain the stated release times with a permissible deviation of 20 %.

General observation

There is an important difference between motors in the ignition protection categories "d" and "e":

In the case of motors with ignition protection category "e" the temperature of the stator winding and also of the rotor must be monitored. The generation of sparks during operation is excluded.

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On motors in ignition protection category "d" the external surface temperature of the housing must be kept below the limiting temperature of the temperature class of the surrounding gas. The generation of sparks in the housing during operation is likely. [2]

Another problem is associated with motors in the ignition protection categories "d" and "e", which are supplied with variable frequency and voltage by a converter.

Irrespective of the possible ignition protection categories "e", "d", "nA" and also "tD", electrical machines must be protected against thermal overloading by one of the two following overload protection devices:

- Motor protection relay
- TMS

Motor protection relay

All the ignition protection categories in use are taken into account in considering this protection device: The protection device must satisfy EN 60947 and its function must be examined and identified by a named test centre as II (2) G D.

Thermistors PTC DIN 44081/82-145
Relais funktionsgeprüft/function tested ⟨Ex⟩ II (2)GD
t_A 28 s/20 °C U_N I_A/I_N 5,0

Figure 5.3 Example for marking

This protection relay can provide effective protection for, but not in Zone 1 or Zone 21.

The response time t_A relates to the test with a stalled rotor. This is the response time to be expected at the rated voltage U_N at an ambient temperature of 20 °C and at the stated relative starting current. It is a measure of the thermal coupling between the sensor and copper.

- The motor protection must also be assured in the event of failure of an outer conductor ("two-wire operation"), e. g. by using tripping devices with phase failure sensitivity.
- On pole-changing motors separate, mutually interlocked tripping devices, are provided for each speed step.
- With Y-Δ-starting the tripping devices are to be switched in circuit with the phase windings and adjusted to the phase current (1/1.73 = 0.58 x rated motor current). The motor is protected by this means when it is not stepped from star to delta (see also EN 60079-14, section 11.2.1).

Temperature measuring sensor protection device as sole protection

Since the temperature sensor is embedded in the end winding, its information is only representative of the temperature of the copper and of the connected direct heat-conducting surface of the stator housing, but not of the rotor temperature.

The thermistor temperature sensor must be electrically insulated and built in to the winding, which impedes the thermal coupling. The electrical insulation hinders the heat transfer from the winding wire to the thermistor and leads to a temperature difference between the copper and the temperature sensor, which can be compensated during continuous operation by appropriate selection of the nominal response temperature.

During a rapid rise in temperature in the short-circuit case (locked rotor), depending on the thermal coupling, a more or less pronounced delay and a temperature overshoot results. Verification of this is provided by the response time t_A an important characteristic [3], which is to be indicated on an additional plate or label.

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In general, motors with current-dependent delayed overload protection devices are permissible for continuous operation with light and infrequent starting cycles, which produce no noticeable additional heating. EN 60079-14 remarks on this in section 11.2.1 as follows:

"In general, motors with current-dependent delayed overload protection devices are permissible for continuous operation with light and infrequent starting cycles, which produce no noticeable additional heating. Motors, which are subject to frequent or heavy starting cycles, are only permissible if suitable protection devices are provided to ensure that the limiting temperature is not exceeded."

Apart from relatively small "stator-critical" motors in ignition protection category "e", this protection device can therefore only be used in ignition protection categories in which the surface temperature of the housing is decisive for the explosion protection: These are the ignition protection categories "d" and "tD".

Operation with frequency converter

The rules relating to erection in EN 60079-14 set the following requirements in section 10.5 with regard to the installation of converter-fed motors in the hazardous area:

Additional requirements for ignition protection category "d":

Motors, which are supplied with variable frequency and voltage, require either:

a) A means (or equipment) for the direct monitoring of temperature with embedded temperature sensors, which are described in the motor documentation, or other effective measures for the limitation of the surface temperature of the motor housing. The motor must be switched off by the protective device. The motor and converter do not have to be tested in combination.

or

b) For this mode of operation the motor must have been subjected to a prototype test with the protection device provided and in association with the converter, which is set out in the descriptions required in accordance with IEC 60079-0, as a complete installation.

Attention

1. *In some cases the highest surface temperature occurs on the motor shaft.*
2. *In the case of motors with connection boxes in ignition protection category "e" care must be taken when using converters with high frequency pulses to ensure that overvoltage peaks and excessive temperatures in the connection housings are taken into account.*
3. *A current-dependent, time delayed protection device (in accordance with section 7a) is not regarded as "another effective measure".*

Version a) corresponds to the customary application, in which the manufacturer provides an EU declaration of conformity and the user must select a suitable converter. The additional requirements for ignition protection category "e" – increased safety in respect of variable frequency and voltage are in accordance with EN 60079-14, section 11.2.4.

"For this operating mode, motors which are supplied by a converter with variable frequency and voltage, must be ***subjected to a prototype test*** *in association with the converter, which is technically described in the documentation required in accordance with IEC 60079-0, together with the protection device provided,* ***as a complete system****, or must be evaluated in accordance with IEC 60079-7."*

Motors in ignition protection categories "nA" must be subjected to a test, together with the converter, as a unit.The successful test is confirmed by the manufacturer in a declaration of conformity (EN 50021, section 10.9.2).

Converter supplied squirrel-cage motors and direct current motors are used in the ignition protection category "d"; three-phase current squirrel-cage motors find application in the ignition protection category "e".

EN 61241-14, section 12.4 [4] requires the following for the ignition protection category "tD":

Ex tD motors, which are supplied with variable frequency and variable voltage, must satisfy the following requirements, either in accordance with a) or b):

a) Means (or devices) for the direct monitoring of temperature by means of embedded temperature-measuring sensors in accordance with the requirements of the documentation of the motor manufacturer, or other effective measures must be provided for the limitation of the surface temperature of the motor housing.

The consequence of the response of the protective device must be the switching off of the motor.

Attention

It is not necessary to test the connection from the motor and converter together.

b) For this operating mode the motor must be subjected to the type test in association with the converter, which is specified in the descriptive documentation and with the protection device provided.

5.5.7 Cables and leads

Only cables and leads of intrinsically safe equipment as well as cable and leads that are used in Zone 0 with other equipment with corresponding approval are permitted for use in Zone 0.

Only cables and leads with thermoplastic, duroplastic or elastomer covers or with mineral-isolated metal covering to be laid permanently are permitted for use in Zones 1 and 2.

The standards to which approved cable and lead types had to conform were specifically listed, in the standards that preceded the current version of VDE 0165, part 1 and DIN VDE 0165 2.91. According to those standards, only cables and leads meeting the requirements of the following standards can be used:

- DIN VDE 0298, part 1
- DIN VDE 0298, part 3
- DIN VDE 0891, part 1
- DIN VDE 0891, part 5
- DIN VDE 0891, part 6

These concrete specifications are no longer included in the current harmonised version of VDE 0165.

If specific requirements are listed more generally in a newer standard, however, the content of an older standard can still be used for more exact specification and to clarify specific questions.

When laying cables and lines in potentially explosive atmospheres, special precautions must be taken against mechanical damage and against corrosion or the effects of chemicals. It may be necessary to lay the cables and lines in protective pipes. It should be noted, however, that closed pipe systems are not permitted.

Connections of cables and leads must be designed in a housing that is certified for the zone in question. Use of loose terminals is not permitted in these housings.

Cable and lead connections can also be executed with epoxide resin, may be including in the casting or may be designed as heat-shrink tubing sleeves. Cast resin fitting in accordance with DIN VDE 0278-1 to 4 or heat-shrink tubing sleeves in accordance with DIN 47632, parts 1 to 4 do not require any declaration of conformity.

Conducting lines that are not used in hazardous areas must be grounded or sufficiently insulated. Insulating with insulation tape is not recommended and should therefore not be used.

Special attention must be paid to connections of cables and leads with equipment for which explosion protection is ensured by the housing (for example in the case of flameproof or pressuring system equipment in Zone 1, for example with drift-proof housings in Zone 2).

Connecting cables or leads must not negatively affect the ignition protection class.

Regardless of the ignition protection class, only cable and lead feed-ins that have been tested and certified in accordance with appendix B of DIN EN 50014 or appendix A of DIN EN 60079-0 can be used. If a cable or lead feed-in is not an integral part of the equipment and was not tested together with the equipment as part of one whole, a separate declaration of conformity must be available for this cable or lead feed-in. It must be identified according to Directive 94/9/EC (ATEX 95) (device group and device category).

Care must be taken during the installation that only cable and lead feed-ins of the same ignition protection class are used in equipment of ignition protection class flameproof enclosure "EEx d".

Cable and lead feed-ins of ignition protection class Increased Safety "EEx e" must never be used in flameproof enclosure equipment, since explosion protection is no longer assured for this device.

Unused openings for cable and lead feed-ins on electrical equipment must be provided with blind stops, which must be suitable for the ignition protection class in question and can only be removed with a tool. In this case as well, special attention must be paid to ignition protection types that ensure explosion protection by means of their housing.

It may be necessary, for example in the case of a flameproof enclosure housing, for the blind stops to be certified together with the equipment.

You can find additional requirements for installing cables and leads in potentially explosive in DIN EN 60079-14 (VDE 0165, part 1), section 9, for example in reference to flexible leads and leads for equipment that can be moved from one place to another.

There are also additional special requirements for intrinsically safe lines as described by section 12.2.2 of EN 60079-14 (VDE 0165, part 1). They are described in greater detail elsewhere.

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5.6 Draft of IEC 60079-14 (VDE 0165-1)

The draft of DIN IEC 60079-14 (VDE 0165-1) Electrical apparatus for areas endangered by gas explosion – part 14: Electrical systems for hazardous areas {with the exception of mining operations) has been available since January 2006. Several new terms are defined, e. g. EPL and these already appear in requirements of the systems in Zone 0, 1 and 2. Since this EPL is already included in the newer standards in relation to apparatus (equipment), it will be dealt with in greater detail at this point.

Equipment protection level (EPL)

This is the level of protection, which is assigned to an item of equipment (or apparatus) on the basis of the risk of it becoming a source of ignition and which characterises the differences between explosion-supporting gas atmospheres, explosion-supporting dust atmospheres and coal mines.

For apparatus for use in an area endangered by gas explosion there are the protection levels "Ga", "Gb", and "Gc". The definition of, for example, the equipment protection level "Ga" becomes clearer when compared with the equipment categories of ATEX 95.

Equipment protection level "Ga"

Apparatus for atmospheres supporting gas explosion with the protection level "very high", which in normal operation, with an expected level of functional faults or with seldom occurring functional faults, does not provide a source of ignition. Such apparatus has a form of ignition protection, which remains effective even on the occurrence of two possible faults (e. g. intrinsic safety – ignition protection category "ia"), or has two independent means of ignition protection (e. g. Ex e and Ex d, which are effective independent of each other).

The EPLs "Ga", "Gb", and "Gc" are specified for atmospheres supporting gas explosion; for combustible dust the relevant EPLs are "Da", "Db", and "Dc" and for equipment group I "Ma" and "Mb".

This means, that the technology has not changed – only the regulations.

Section 4.1 general requirements contains the statement:
In order to ease the selection of electrical apparatus for a specific purpose and also the correct layout of electrical installations, the hazardous area has been divided into Zones 0, 1 and 2 in accordance with IEC 60079-10 and also into the requisite equipment protection levels, based on the evaluation of the consequences of ignition taking place.

In section 5 – The selection of electrical apparatus, the draft declares, that the previous practice of the selection of equipment in accordance with specified zones (the level of risk corresponds to the probability of the occurrence of explosive atmospheres) should be supplemented with an assessment of the actual risk of explosion that is involved. A correct evaluation of the risk is required, with consideration of all factors.

If an evaluation of the risk indicates that the consequences of an ignition are more severe than normal, it may be necessary to increase the EPL requirement to an extent that, for example in an area designated Zone 2, it may be necessary to use apparatus, which satisfies the requirements for EPL "Gb".

If in the opposite case the risk evaluation indicates that the consequence of an ignition are less severe than normal, it could be possible, for example, to reduce the EPL requirement to the level in which in an area designated as Zone 1 the apparatus used need only satisfy the requirements for EPL "Gc".

No further comments will be made concerning the draft standard.

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5.7 Protection against electrostatic charges

Among possible ignition sources that may cause a potentially explosive atmosphere to ignite, static electrical discharge is a frequently underrated ignition source. Special attention must be paid to it, because is caused unintentionally and the conditions that allow it to occur are often not recognised.

Static charges can be caused by such things as rubbing (cleaning), stroking along with articles of clothing, dividing up a substance (reducing, spraying, pulverising) as well as liquids that can acquire a charge flowing through a pipe, whether or not the pipe is conducting.

If there is sufficient charge and the electrical fields are high enough as a result, there may be discharges (gas discharges) that can ignite potentially explosive atmospheres.

Discharges capable of igniting can occur

- between an isolated or grounded object capable of conducting and a charged isolated object capable of conducting
- between an isolated or grounded object capable of conducting and a charged isolated material capable of not conducting

The charging process is determined by many factors such as the speed of contact separation, contact pressure, surface resistance of the contact partners involved, relative humidity and temperature, nature of the surface, etc. so that a specific process may occur many times without anything noteworthy happening, but just one time ignition will occur.

Since ignition cannot occur in potentially explosive atmospheres as a result of electrostatic discharge, protective measures in accordance with BGR 132 (guidelines for preventing ignition hazards resulting from electrostatic charge – "Static electricity" guidelines) are required in potentially explosive atmospheres.

In specific terms, the following measures should be observed against electrostatic charges:

a) The floor in the potentially explosive atmospheres (with the exception of Zone 2) must be capable of conducting an electrical current (leakage resistance $< 10^8\ \Omega$).

b) Footwear capable of conducting electricity must be worn in potentially explosive atmospheres (work safety boots capable of conducting electricity, penetration resistance $< 10^8\ \Omega$).

c) Use of conducting gloves, for example for cleaning jobs.

d) If v-notch belts are made of conducting material, they can also become ignition sources due to electrostatic charge. It must therefore be ensured that all v-notch belts that are used are electrostatically conductive. In accordance with BGR 132, section 7.1.5.2, the following condition must be met:

$RB \leq 10^5\ \Omega m$

R is the resistance of the drive belt in W measured between an electrode (located on the mounted drive belt in the middle between the disks on the inside) and the pulley.

B is the width of the belt or twice the width of the edge of the v-notch belt in m.

e) To prevent dangerous electrostatic charging when storing used dust rags, dust rags should not be collected in plastic bags made of non-conductive material.

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f) In accordance with BGR 132, section 7.2.4.1.4 the upper limiting value for hoses used to fill tanks that do not contain any metal inserts of 10^6 Ω/40 m between the ends of the hose, with an upper limiting value of 10^6 Ω for the surface-related penetration resistance, must not be exceeded. The limit value of 10^6 Ω must be observed for hose lines made of non-conducting material with metal inserts. The grounding must be ensured through metal connection pieces.

g) If clothing that is typical for the job is worn generally no discharges capable of igniting will be caused if persons are wearing footwear capable of conducting electricity (penetration resistance $< 10^8$ Ω) and the floor is sufficiently capable of conducting a leakage current (leakage resistance $< 10^8$ Ω). Therefore, no additional measures are required in terms of clothing in areas of Zones 1 and 2. It should be noted, however, that taking off articles of clothing can result in discharge capable of igniting, and must therefore be avoided in Zone 1.

h) In connection with considering the capability of system parts of acquiring an electrostatic charge, special attention should also be paid to potential equalisation. Because of this, all conducting parts must be connected with each other.

For additional requirements for avoiding electrostatic charges and a list of limit values as well as an evaluation of the danger associated with different types of discharge, please refer to BGR 132.

It also describes the measurement process for determining leakage resistance and surface resistances.

This trade association regulation also describes concrete protection measures for certain work processes such as filling, emptying and cleaning tanks or coating and painting foil.

BGR 132 – Regulations "Static Electricity" is essential reading for operators of systems in hazardous areas, and the protective measures described there are essential.

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5.8 References

BetrSichV	"Regulation regarding Safety and Health Protection in Providing Work Equipment and its use in Work, Safety in Operating Systems Requiring Monitoring and the Organisation of Industrial Work Protection"(Industrial Safety Regulation).
GefStoffV	Regulation for Protection from Hazardous Substances (in German: Gefahrstoffverordnung)
ExVO	Eleventh regulation on the Device Safety Law (regulation on placing devices and safety systems in circulation for hazardous areas – explosion protection regulation – 11th GSGV)
ATEX 137	Directive 1999/92/EC of the European Parliament and Council of December 16, 1999 regarding minimum requirements for improving health protection and safety of employees who may be endangered by a potentially explosive atmosphere.
ATEX 95	Directive 94/9/EC of the European Parliament and Council of March 23,1994 for harmonising statutory requirements of member nations for devices and protection systems intended for use in potentially explosive atmospheres
DIN EN 1127-1	Potentially explosive atmosphere – explosion protection, part 1: basic principles and methodology
BGR 104 (earlier ZH 1/10)	"Rules for Safety and Health Protection at Work" Explosion protection rules (EX-RL)
BGR 132 (earlier ZH 1/200)	Directives for preventing ignition hazards resulting from electrostatic charge – "Static Electricity" directive
DIN VDE 0100	Setting up high-voltage systems with nominal voltages up to 1000 V
DIN EN 60079-10 (VDE 0165, part 101)	Electrical equipment for explosive gas atmospheres, part 10: Classification of explosive gas hazardous areas
[1] – DIN EN 60079-14 (VDE 0165, part 1)	Electrical equipment for explosive gas atmospheres part 14: Electrical systems in hazardous areas (except for underground construction)
DIN EN 50281-1-2 (VDE 0165, part 2)	Electrical equipment for use in areas with flammable dust Main section 1: Electrical equipment with protection through housing Part 2: Selection, set-up and maintenance
Electrical explosion protection in accordance with DIN VDE 0165	Lienenklaus/Wettingfeld: Electrical explosion protection in accordance with DIN VDE 0165 VDE series 65, 2., revised edition 2001, VDE Published by VDE, Berlin and Offenbach
[2]	Chief Eng. Greiner Explosion protection for geared motors (Danfoss Bauer GmbH)
[3]	Chief Eng. Greiner ATEX conform VF motors (Danfoss Bauer GmbH)
[4]	EN 61241-14, Electrical apparatus for use in the presence of combustible dust

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6 Setting up systems with intrinsically safe circuits

6.1 Introduction

DIN EN 60079-14 VDE 0165, part 1 specifies additional requirements for ignition protection type "i" – intrinsic safety (under section 12):

Attention

"When intrinsically safe circuits are installed, a fundamentally different installation philosophy must be observed. In all other types of installation, precautions are taken so include electrical power in the installed system in such a manner that an area subject to the danger of explosion cannot be ignited. In contrast to this, the entire intrinsically safe circuit must be protected against penetration of energy from other sources, so that the safely limited energy levels in the circuit are not exceeded, even if there is a broken lead, a short circuit or grounding of the circuit.

It follows from this principle that the goal of installation rules for intrinsically safe circuit is to maintain proper separation from other circuits." [1]

The "safely limited energy levels" must be determined through proof of intrinsic safety. This demonstration is part of the explosion protection document that must be created and kept up to date in accordance with § 6 if the Industrial Safety Ordinance (BetrSichV) before installation tasks are accepted.

After determination of intrinsic safety, it is then the task of the installer to perform the installation according to the "additional requirements" of EN 60079-14, especially in terms of identifying circuits, maintaining distances and separating different circuits.

6.2 Proof of intrinsic safety

DIN EN 60079-14 requires (under 12.2.5, Proof of intrinsic safety), that the requirements listed there must be satisfied, provided no system description is available for the entire intrinsically safe circuit. These requirements are subdivided according to

- intrinsically safe circuits with only one piece of related equipment (simple intrinsically safe circuit),
- intrinsically safe circuits with more than one piece of related equipment (interconnection).

A theoretical calculation is required for the Interconnection. The form of the descriptive system document is not specified, but it must be developed and maintained in such a manner that all relevant information for a specific system can be easily found.

In the national preface to DIN EN 60079-14, reference is made to the special features of active intrinsically safe circuit, both with concentrated inductances and concentrated capacitances. The PTB report ThEx-10 should be used for proof of intrinsic safety for use in Zone 0.

DIN EN 60079-14 contains or refers to the following procedure for proving intrinsic safety:

- The circuit includes only one piece of related electrical equipment.
  DIN EN 60079-14, section 12.2.5.1
- The circuit contains more than one piece of related electrical equipment that are active in normal operation or in the event of failure, but all of them have one linear current/voltage path characteristic. DIN EN 60079-14, appendix A
- The circuit includes more than one piece of related electrical equipment that are active in normal operation or in the event of a failure, and at least one of them has a non-linear current/voltage path characteristic. PTB report ThEx-10 (informative appendix to DIN EN 50039)

If the hazard evaluation for creating the explosion protection document requires it, the PTB report ThEx-10 should also be used to prove the intrinsic safety of a simple circuit.

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6.2.1 Proof of intrinsic safety of a simple intrinsically safe circuit

The highest permissible levels for inductance, capacitance or the L/R/ ratio as well as the temperature must not be exceeded, including cables and lines.

The following applies:

Electrical parameters				
Intrinsically safe equipment		Cables/leads		Related equipment
U_i			$\geq$	U_o
I_i			$\geq$	I_o
P_i			$\geq$	P_o
L_i	+	L_c	$\leq$	L_o
C_i	+	C_c	$\leq$	C_o

Table 6.1 Electrical parameters of a simple intrinsically safe circuit

The temperature class can be determined for simple equipment according to section 12.2.5.1 of DIN EN 60079-14.

As an example, proof of a simple intrinsically safe circuit consisting of a proximity switch and a switch amplifier will be provided in accordance with 12.2.5.1 of DIN EN 60079-14.

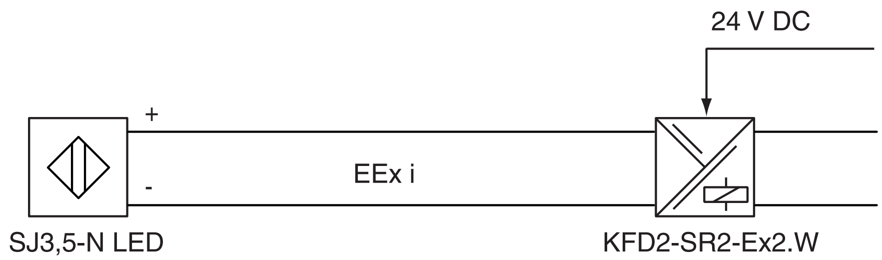

Figure 6.1 Intrinsically safe circuit for monitoring flap position

Related equipment		Manufacturer	EC prototype test certification	U_o [V]	I_o [mA]	P_o [mW]	L_o [mH]	C_o [nF]	Ex group
Model number	Type								
Switch amplifier	KFD2-SR2-Ex2.W	Pepper+Fuchs GmbH	PTB 00 ATEX 2080	10.5	13	34	3	620	IIC

Seq. No.	Intrinsically safe electr. equipment		Manufacturer	EC prototype test certification	U_i [V]	I_i [mA]	P_i [mW]	L_i [mH]	C_i [nF]	Ex group
	Model number	Type								
1	Proximity switch	SJ3,5-N LED	Pepper+Fuchs GmbH	PTB 99 ATEX 2219	16	25	64	0.25	50	IIC
2										
Cable inductance and capacitance:			L_c = 700 µH/km C_c = 45.9 nF/km l = 600 m					0.42	27.54	
Total inductance and capacitance:			$\Sigma L_i / \Sigma C_i$					0.67	77.54	
Conditions for intrinsic safety:			U_o	$\leq$	U_i	10.5 V	$\leq$ 16 V			
			I_o	$\leq$	I_i	13 mA	$\leq$ 25 mA			
			P_o	$\leq$	P_i	34 mW	$\leq$ 64 mW			
			L_o	$\leq$	$\Sigma L_i + L_c$	3 mH	$\geq$ 0.67 mH			
			C_o	$\leq$	$\Sigma C_i + C_c$	620 nF	$\geq$ 77.54 nF			

Table 6.2 Proof of intrinsic safety of a simple intrinsically safe circuit (example)

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Taking into consideration the concentrated inductances and capacitances present in the circuit, the proof of intrinsic safety provided using the PTB report ThEx-10 for Explosion group IIC specifies that at a maximum inductance of 1 mH in the circuit, a total capacitance of 500 nF is permitted. The connectable capacitance specified on the EC declaration of conformity C_o = 620 nF is derived from exact calculation permissible for the PTB using report ThEx-10.

Summary: Proof of intrinsic safety is provided even under these conditions.

6.2.2 Proof of intrinsic safety for circuits with multiple pieces of related equipment (interconnection)

Calculated proof of intrinsic safety

When multiple active pieces of related equipment are interconnected, according to the EC declaration of conformity, their electrical limits must not be used directly to prove intrinsic safety.

The interconnection of the individual pieces of related equipment should be regarded as a **single** piece of electrical equipment for determining the new limit value.

Depending on the interconnection or possible failure case, series, parallel switching or (especially in the case of a failure) mixed interconnection (series or parallel switching) should be considered.

EN 60079-14 describes the calculated proof of intrinsic proof when interconnecting related electrical equipment with linear current/voltage output path characteristic. This related electrical equipment includes active sources in normal operation or only in the event of failure. This procedure does not take into account the occurrence of inductances and capacitances together and applies only to a limited open circuit voltage range when determining permissible inductances. Since the interconnection is not permissible for Zone 0, these restrictions need not be taken into consideration in most cases.

The PTB report ThEx-10 of November 1999 includes these restrictions. Calculated spark modeling makes it possible to take into account the safety factor required for Zone 1 for non-linear sources and for occurrence of both inductances and capacitances.

Thus, the PTB report ThEx-10 can be used for all versions of the proof of intrinsic safety:

- Simple interconnection with or without concentrated inductances and concentrated capacitances (the characteristic path of the related equipment has no meaning in this case);
- Interconnection of multiple pieces of related equipment (any characteristic path type) with or without concentrated inductances and concentrated capacitances.

6.2.3 Determining the new limit values according to EN 60079-14

EN 60079-14 describes (in appendix A) the proof of intrinsic proof for intrinsically safe circuits with more than one piece of related electrical equipment with linear current/voltage path characteristic.

Appendix B describes the procedure for determining the maximum system voltages and currents in an intrinsically safe circuit according to appendix A.

Protection level "ib" must be considered for the interconnection, even if all corresponding equipment corresponds to protection level "ia". Because of this, interconnections of this type are not permitted for Zone 0.

The limit values for open circuit voltage can be calculated for

a) **Parallel operation:** U_o- from the greatest of individual open circuit voltages/ I_o- from the total of all individual open circuit voltages

b) **Series switching:** U_o- from the total of all individual open circuit voltages/ I_o- from the greatest of all individual short circuit currents

c) **Mixed circuity:** U_o or I_o from the total of all relevant individual values U_o or I_o.

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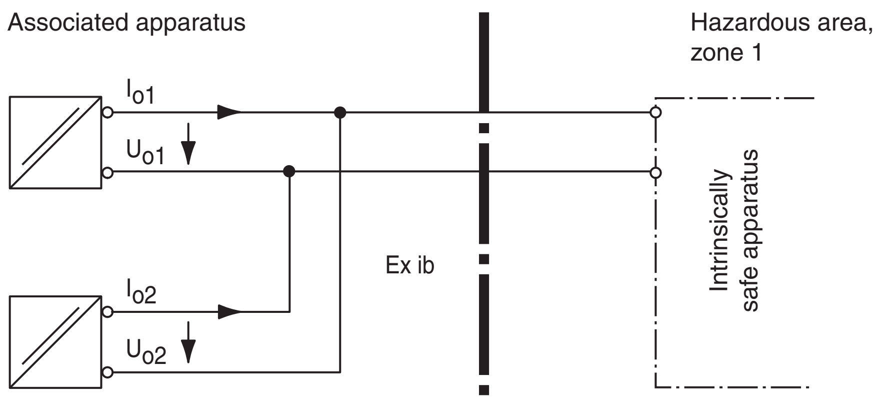

Figure 6.2 Parallel operation – total of all currents

New maximum system values: U_o $= \max. (U_i)$

I_o $= \Sigma I_{oi} = I_{o1} + I_{o2}$

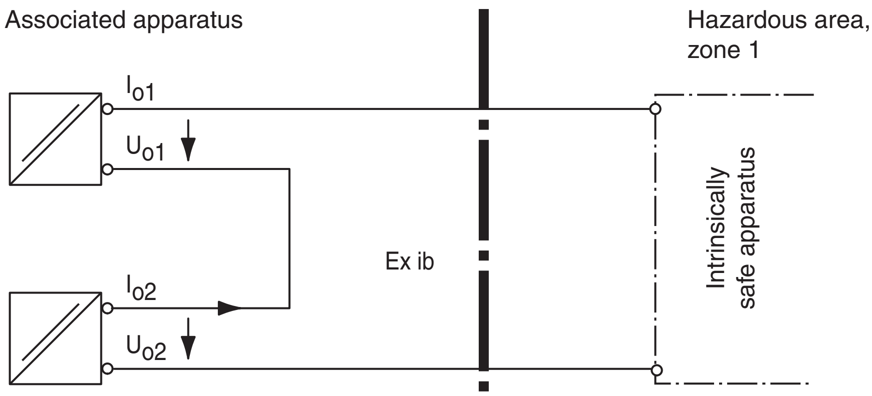

Figure 6.3 Series switching – addition of voltages

New maximum system values: U_o $= \Sigma U_{oi} = U_{o1} + U_{o2}$

I_o $= \max. (U_{oi})$

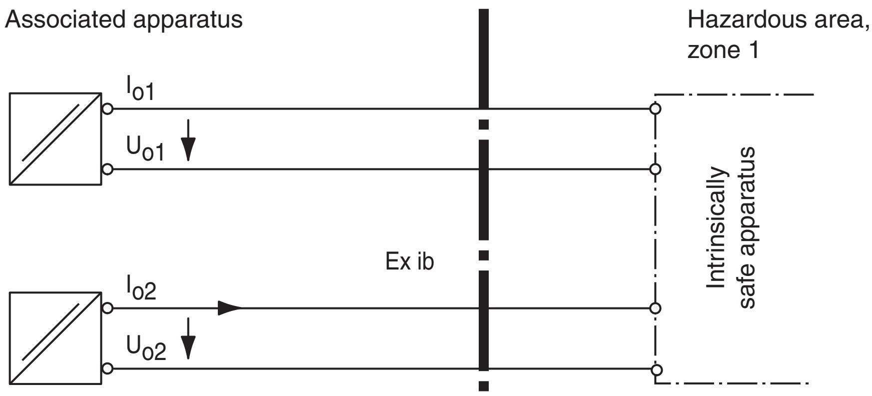

Figure 6.4 Parallel and series switching – addition of voltages and addition of currents

New maximum system values: $U_o = \Sigma U_{o\,i} = U_{o1} + U_{o2}$ or $U_o = \max. (U_{oi})$

$I_o = \max. (I_{oi})$ or $I_o = \Sigma I_{o\,i} = I_{o1} + I_{o2}$

These method of consideration should be applied to all interconnections that are simple enough to grasp easily. It proceeds from the most unfavourable conditions and thus ensures a high degree of safety. The maximum permissible limit values U_o, I_o, L_o and C_o should be derived from the explosion limit curves of EN 50020 in accordance with the calculation procedure in EN 60079-14.

EN 50020 (April 1996) provides a list of all explosion limit curves for ohm and capacitive circuits in table format.

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6.2.4 PTB report ThEx-10

PTB report ThEx-10 describes a generally applicable procedure for creating a proof of intrinsic safety. It takes into account the presence of both concentrated inductance and concentrated capacitances in the circuit and any type of characteristic path for interconnecting multiple pieces of related equipment.

When multiple pieces of related equipment are interconnected and they do not all have one linear current/voltage characteristic path, a calculated additive determination of limit values is not possible. The current/voltage characteristic path in effect in normal operation is determined as a total output characteristic path by graphic addition of the current and/or voltage characteristic path similar to 6.2.3. This total output characteristic path may be represented as a limit curve diagram in which proof of intrinsic safety is given.

There are 5 limit curve diagrams for Explosion groups IIB and IIC each. They may be distinguished by the size (0.15 mH; 0.5 mH; 1 mH; 2 mH; 5 mH) of the permissible inductance of the interconnection. Each of these diagrams consists of an inductive limit characteristic path for the linear and rectangular source and a family of curves for determining the maximum permissible capacitance. Determining the intrinsic safety depending on the inductance includes intrinsic safety for the ohm-related behaviour of the interconnecting. Thus there is no ohm limit characteristic path.

The first steps when providing proof of intrinsic safety are to determine Explosion group IIC or IIB and select one of five possible ignition limit curve diagrams as a function of the lowest permissible inductances. It is derived from the total of all concentrated inductances present in the circuit that must be smaller than the lowest permissible inductance L_o and that can be connected of all individual pieces of related equipment.

6.2.5 Procedure for proving intrinsic safety

When proving intrinsic safety for a **simple circuit without** simultaneous occurrence of **concentrated inductances and capacitances** it suffices to compare Ex i parameters according to the EC declaration of conformity (see section 6.2.1).

If concentrated inductances and capacitances are simultaneously present in a simple intrinsically safe circuit, however (with only one piece of related equipment), the comparison of relevant Ex i characteristic values described under section 6.2.1 will not ensure the desired system safety, since the characteristic values L_o and C_o apply only to the case or purely inductive or purely capacitive load on the circuit if they were derived from the explosion limit curve (see replacement circuit diagram in the explosion limit curves).

For the **circuit described under 6.2.1 with concentrated inductances and capacitances,** selecting the ignition limit curve diagram for group IIC with a permissible inductance of $L_i + L_c = 0.67$ mH, thus less than 1 mH, will result in selection of diagram IIC; 1 mH. The current/voltage current path characteristic of switch amplifier KFD2-SR-Ex2.W must be inscribed into this diagram. Its position is determined by the values $U_o = 10.5$ V and $I_o = 13$ mA. Since neither the limit line of the linear source nor that of the rectangular source is intersected, this circuit is intrinsically safe if the total capacitance of the circuit is less than 500 nF (the beam for this capacitance is not intersected by the current/voltage characteristic path).

The starting point for proving intrinsic safety for the **interconnection** of multiple pieces of related equipment is the graphic creation of a total output characteristic path for the interconnection. The same considerations in terms of the type of interconnection and possible faults must be applied as are specified in EN 60079-14, appendix A and B for interconnections of multiple pieces of equipment with a linear output characteristic. The only difference is that now a graphic determination must be performed instead of a calculated one.

The graphically determined total output characteristic path(s) must be inscribed into the limit curve diagram according to equipment group IIB or IIC and the permissible total inductance.

Intrinsic safety is proven if the limit curve of the rectangular source is not intersected at any point on the diagram and the intersection point of the maximum current and maximum voltage in the diagram is included by the limit curve of the linear source. The highest permissible capacitance of the interconnection is derived from the limiting family of curves for capacitance with evaluation of the maximum voltage.

Note

Because of many additional conditions, exceptions and other assumptions cited in PTB report ThEx-10 [3], it is not possible to go into greater detail with this report here. We simply suggest you read these details in the report. This report is attached to EN 50039 as an informative appendix.

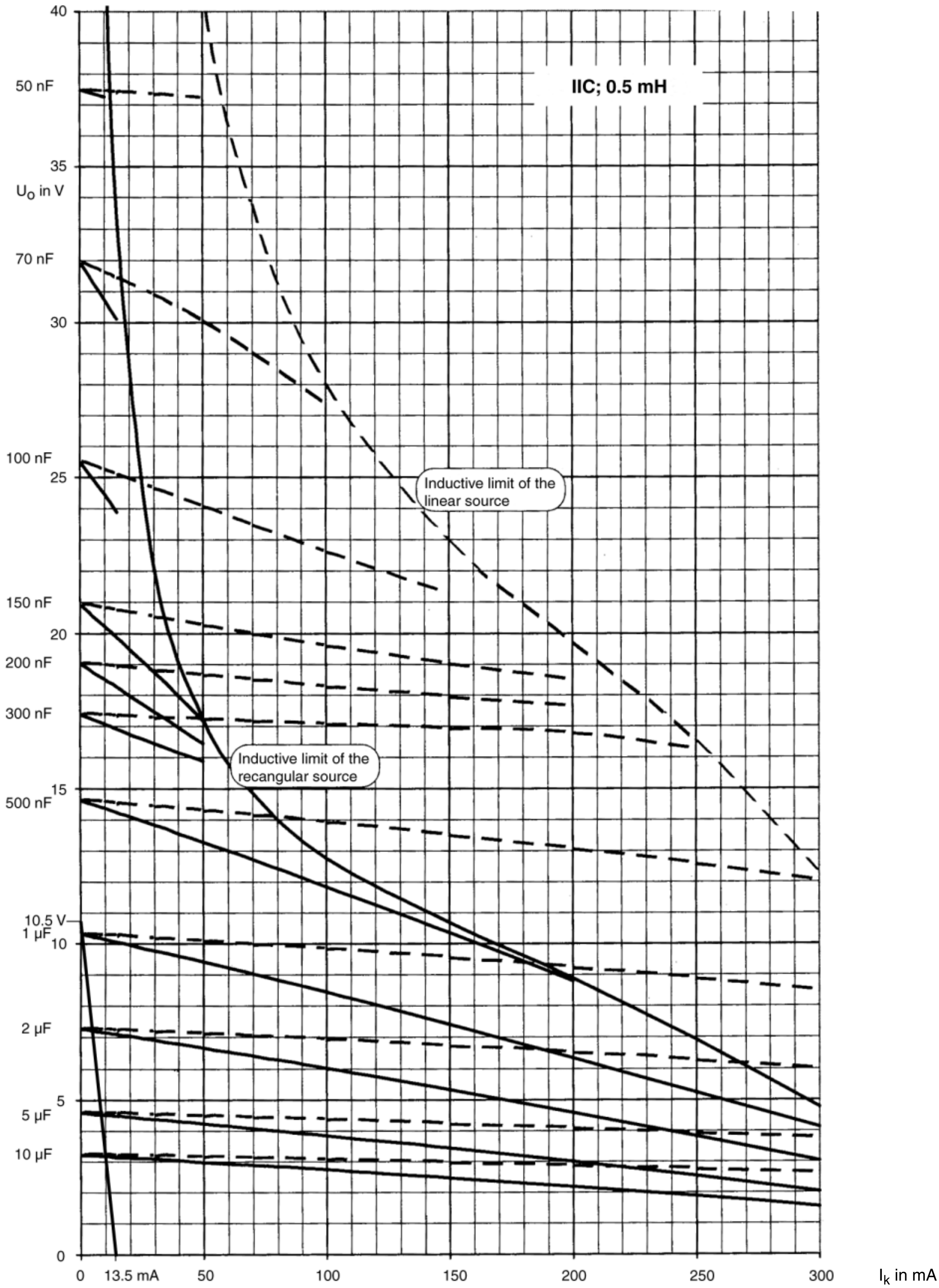

Figure 6.5 Limit curve diagram for general source current path characteristic

6.3 Requirements for setting up intrinsically safe circuits in the Zones 1 and 2

The requirements noted in detail in EN 60079-14 under 12.2 Systems for Zones 1 and 2 can only be explained with some modifications and in summarised format below. It is essential to read through the standard.

6.3.1 Equipment requirements

- Intrinsically safe and related equipment, at least protection level "ib"
- No proof or marking is required for simple equipment, although it must meet the requirements of DIN EN 50020 if intrinsic safety depends on it
- Install related equipment without additional ignition protection outside of the hazardous area
- Maximum supply voltage no greater than U_m of the corresponding equipment
- Components, cable and lines of the equipment should be fitted in the IP20 housing.

6.3.2 Installation of intrinsically safe circuits

- Only insulated cables and lines (test voltage ≥ 500 V AC or 750 V DC)
- Minimum diameter of an individual line in an hazardous area 0.1 mm
- Electrical characteristic values (C_c and L_c) or (C_c and L_c/R_c) must be determined. DIN EN 60079-14 / 2004 states in 12.2.2.2 – Electrical parameters of cables and leads – that the following cable parameters are applicable, when these are unknown: 200 pF/m and either 1 µH/m or 30 µH/Ω
- Protection of intrinsically safe circuits against external electrical or magnetic fields by using shields and/or twisted wires or by maintaining an appropriate distance
- In addition to requirements for avoiding damage, cables and lines with intrinsic
  - must be directed separately from all cables and lines with non-intrinsically safe circuits, or
  - cables and lines of intrinsically safe or non-intrinsically safe circuits are protected, metal-coated or shielded.
- Wire lines of intrinsically safe and non-intrinsically safe circuit must not be laid in the same line.

6.3.3 Connecting intrinsically safe circuits

- Connection terminals for intrinsically safe circuits must be marked as such
- Permissible separation of connection terminals, intrinsically safe from non-intrinsically safe circuits (for example by a dividing wall or air gap ≥ 50 mm)
- Minimum air gap of 3 mm between non-isolated conducting parts and grounded parts or other parts capable of conducting and separated intrinsically safe circuits 6 mm.

6.3.4 Installation and marking of cables and lines

- Separation of intrinsically safe and non-intrinsically safe circuits in cable bundles or channels with a layer of insulating material between or grounded metal piece between (not required with shielding or coating for intrinsically safe or non-intrinsically safe circuits),
- unused wires of multi-wire cable must insulated from each other and against ground with suitable terminating pieces (if they are in the cable, for example there is already an existing ground connection via the related equipment),
- cables and lines of intrinsically safe circuits must be marked,
- if covers or coatings are marked by a colour, the colour that is used must be light blue. In this case, cables and lines coated in light blue must not be used for other purposes,

- if intrinsically safe or all non-intrinsically safe cables and lines are protected, coated in metal or shielded, marking of intrinsically safe cables and lines is not required,
- if a blue neutral line is present in MSR cabinets, switching or distributing systems, measures must be taken to prevent mix-ups, for example laying wires together in light blue cable harness, labeling or clear layout and spatial separation.

6.3.5 Multi-wire cables and lines with more than one intrinsically safe circuit (basic requirements and fault considerations)

- Conductor insulation at least 0.2 mm thick
- Test voltage of conductor insulation at least 500 V_{eff} (or 2x nominal voltage),
- Special requirements for insulation between
  - all individual wires connected to each other and the shielding/protection (500 V_{eff} AC or 750 V DC),
  - half of all individual wires connected to each other (1000 V_{eff} AC or 1500 V DC).

Note

The device categories required in intrinsically safe circuits for the respective zones (Zone 1 category 2) may be seen on the declarations of conformity. They must meet all fault requirements.

The following fault considerations must be made for cables and lines:

Type A: Meets basic requirements, wires for each intrinsically safe circuit are shielded

Type B: Meets basic requirements; permanently laid, mechanically protected/U_{omax} < 60 V,

Type A and B are not subject to any fault considerations. Two short circuits and four line breaks must be assumed for other cables (exception: 4 x safety factor).

6.3.6 Grounding of intrinsically safe circuits and conducting shields, multiple grounding of conducting shields

- Circuits must be set up ground free or connected at one point to a potential equalisation system (extends through the entire range of the circuit)
- Resistance (0.2 ... 1) MΩ for diverting electrostatic charges does not count as grounding
- (Required for safety reasons) Grounding to a potential system by the shortest possible way
- Multiple grounding permitted if the circuit was divided into multiple galvanically separated partial circuits, each of which is grounded at one point
- Cross-section of ground connection (copper): 2 x at least 1.5 mm^2 or 1 x at least 4 mm^2.

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Grounding of conducting shields:

- Required conducting shield must only be grounded at one point, typically at the end in the area not subject to the danger of explosion
- If a grounded intrinsically safe circuit is running in a shielded cable, the shield should be grounded in the same place as the intrinsically safe circuit
- The shield should be grounded at one point in the potential equalisation system if a ground-free intrinsically safe circuit is running in the shielded cable
- If it is ensured to a high degree that there is potential equalisation between each end of the circuit, the cable and line shields must be connected on either end of the cable and line and, if necessary, on intermediate points on the ground
- Multiple grounding via small capacitor (for example 1 nF, 1500 V, ceramic) is permitted provided the total capacitance does not exceed 10 nF

In special cases (high resistance of shield or shielding required against inductive interference), multiple grounding is permitted in accordance with Fig. 2, section 12.2.2.4 of DIN EN 60079-14 if:

- There is a ground conductor present (at least 4 mm^2)
- Insulation test at 500 V is passed in different tests
- Insulated grounding conductor and shield are only connected with ground at one point (normally at the end of the cable in the area not subject to the danger of explosion)
- The insulated grounding conductor is laid with protection
- The L/R ratio of the cable and line that is applied together with the insulated grounding conductor meets the requirements of intrinsic safety.

6.3.7 Floating circuit

Since an intrinsically safe circuit can only be grounded at one point, additional grounding for use with Zener barriers (for example on the sensor) is not permitted. Zener barriers must be set up in the secure area. If the immediate grounding causes interference with measurements, it is possible, by interconnecting two Zener barriers, to keep the measurement lines quasi ground-free up to the Zener voltage (floating circuit).

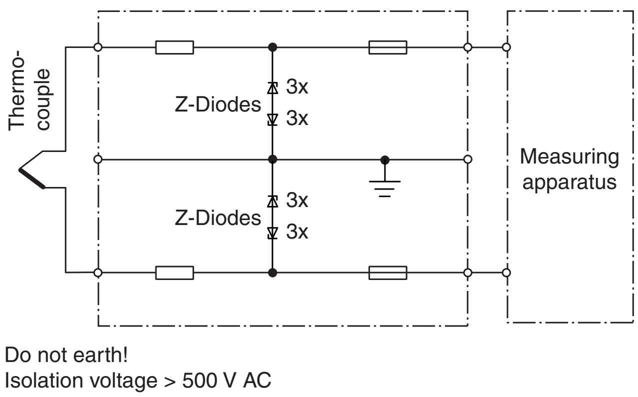

Figure 6.6 Floating circuit principle

Care should be taken in this regard that two intrinsically safe circuits **are interconnected**. The highest levels of current and voltage and the new permissible external inductances and capacitance must be determined. The DIN-Rail Housing catalogue of the Process Automation division of Pepperl+Fuchs has selection tables describing Zener barriers with safety-related rating values for the separate channels as well as series and parallel circuits of the channels. There must be no double grounding for this circuit either, i. e. the thermocouple must be set up insulated.

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6.4 Requirements for setting up intrinsically safe circuits in den Zone 0

In addition to the requirements for Zone 1, the following requirements must be met:

- Equipment of protection level "ia" is required in accordance with DIN EN 50020
- Circuits with more than one piece of related electrical equipment are not permitted in Zone 0, since their protection level must be considered as "ib" even if all equipment corresponds to protection level "ia"
- Galvanic separation of intrinsically safe and non-intrinsically safe circuits in related equipment is preferred
- When using related equipment without galvanic separation, impedance from the connection point to the grounding point of the high-voltage mains network (TN-S power supply) less than 1 Ω, in addition separated transformer for equipment fed through mains power supply is required
- For functionality reasons, grounding required outside of Zone 0 (but as close as possible to the equipment for Zone 0), preferably at a distance of up to 1 m
- Detailed lightening protection measures for intrinsically safe circuits outside construction areas or above ground level.

6.5 Maintenance of intrinsically safe systems

DIN EN 60079-14 VDE 0165, part 10 "Checking and maintenance of electrical systems in areas subject to the danger of explosion (excepting underground construction)" includes additional requirements for protection type Intrinsic safety in section 5.3:

- Maintenance tasks for intrinsically safe systems can be performed on equipment that is under voltage provided certain requirements are observed
- Ground connections of safety barriers must not be removed before circuits to the hazardous area are disconnected
- Tasks in the hazardous areas are limited to:
  - disconnecting, removing or replacing parts,
  - adjusting all settings required for calibration,
  - removing and replacing plug-in components and sub assemblies,
  - use of check instruments specified in the documentation.
- After the check, the intrinsically safe system/equipment must meet all requirements in accordance with system documentation.
- The documentation must include the following individual details:
  - Proof of intrinsic safety
  - Manufacturer, type and certificate number of the equipment, category, equipment group, temperature class
  - Electrical parameters (inductance, capacitance, length, type and path of cables and lines)
  - Special requirements according to the equipment certificate
  - Installation position of each piece of equipment in the system.

The following items must also be checked:

- Clear marking of intrinsically safe circuits
- Installation must match system documentation
- Separation modules between intrinsically safe and non-intrinsically safe circuits
- Cables and lines and shields for them
- Consistency of grounding for non-galvanically isolated circuits; ground connections to ensure intrinsic safety
- Grounding and/or insulation of intrinsically safe circuits
- Separation between intrinsically safe and non-intrinsically safe circuits
- Minimum distances must be observed.

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6.6 References

[1] DIN EN 60079-14: 1998 Electrical equipment for explosive gas atmospheres part 14: Electrical systems in areas subject to the danger of explosion (except for underground construction)

[2] DIN EN 50020: 2001 Electrical equipment for potentially explosive atmospheres, intrinsic safety "i"

[3] Ulrich Johannsmeyer, Martin Krämer PTB report ThEx-10 Interconnection of non-linear and linear intrinsically safe circuits

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7 Dust explosion protection

7.1 Dust explosions and their causes

There is danger of a dust explosion when manufacturing, processing, transporting, storing or packaging flammable dust.

Following is a list of a number of jobs that entail the risk of dust explosions:

- Grinding/drying coal
- Filling coal dust silos
- Suctioning off and conveying wood dust in filters and separation systems; transferring grain and placing/keeping it in silos
- Grinding, mixing and mechanically conveying organic products (grain, feed material, sugar, synthetic materials, dyes, pharmaceutical products)
- Spray drying organic products (milk)
- Drying, granulating and coating in fluidised bed equipment (clear sludge processing)
- Grinding light metals and their alloys
- Manufacturing and processing metal powders

According to a study of trade unions associated with the food and restaurant industries, "Dust explosions – food, feed materials and grain dust", it is safe to assume that an average of one dust explosion per day occurs in Germany. One fourth of these are triggered by dust of food or feed material.

Percentage of dust types in dust explosions [1]:

- Wheat dust 24 %
- Wood dust 34 %
- Synthetic material 14 %
- Metal dust 10 %
- Coal dust 10 %
- Paper dust 2 %
- Other types of dust 6 %

The following ignition sources were determined for dust:

- Mechanical sparks 30 %
- Static electricity 9 %
- Friction 9 %
- Hidden smouldering pockets 9 %
- Fire 8 %
- Hot surfaces 6.5 %
- Spontaneous combustion 6 %
- Welding work 5 %
- Electrical equipment 3.5 %
- Other 13.5 %

Dust capable of igniting occurs when fine solid particles with a granularity of less than approx. 0.4 mm are generated from flammable materials. These particles may be generated intentionally (for example by grinding or pulverising) or unintentionally (for example due to abrasion). According to an analysis of the Food and Restaurant trade union, from 0.1 to 2.5 percent by weight of fine particles occurs when large granularity materials are transported and processed.

If a cube with a length of 1 cm on one edge is divided into particles with a side length of 0.001 mm, the result is an overall surface of 6 m^2 that is capable of reacting with oxygen. While the cube could burn, the dust explodes. [2]

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7.2 Safety-related characteristic values of dust

These safety-related characteristic values are not natural constants. Instead they are experimentally determined properties of substances used to characterise dust. A large number of these characteristic values are required to select equipment. Others are basic parameters for design-related or tertiary explosion protection. This is not the appropriate place for a discussion of the problem of limiting the effects of an explosion to an acceptable level through

- Explosion-proof design
- Explosion pressure release
- Explosion suppression
- Preventing transfer of the explosion

This is especially important in the case of dust explosion protection (see section 3.6).

It is also not possible to go into all important safety-related characteristic values. An extensive body of reference material is available for this purpose. A few important publications are listed below:

- VDI Directive 2263 Dust fires and dust explosions
  - Sheet 1 Determining safety-related characteristic values
  - Sheet 2 Inertisation
  - Sheet 3 Explosion-pressure-proof containers and equipment; calculation, construction and testing
  - Sheet 4 Suppressing dust explosions
  - Sheet 5 Risks and evaluations – protective measures, explosion protection for fluidised bed systems

- VDI Directive 3673 — Pressure release of dust explosions
- TRD 413 — Coal dust fires in steam boilers
- TRD 415 — Fluidised bed fires in steam boilers
- Introductory manuals related to technical connections for system safety (German abbreviation TAA)
- TAA-GS 15 — Dust/air mixtures capable of exploding and the regulation governing malfunctions
- BGV C15 — Coal dust systems (earlier VBG 3)
- GESTIS-Staub-EX — Database on characteristic values of dust related to fires and explosions (main association of commercial trade unions)
- BIA Report 12/97 — Characteristic values of dust related to fires and explosions
- BGI 747 — Circular R003 System safety – Determining and evaluating safety-related characteristic values

Important parameters and characteristic values are:

- Possibility of dust explosion
- Explosion limits
- Minimum ignition power
- Median value
- Explosion pressure, DE dust explosion classes
- Ignition temperature
- Smoulder temperature
- Spontaneous combustion temperature
- Combustion behaviour (combustion index (CI), combustion speed)

7.2.1 Possibility of dust explosion

A material is capable of being involved in a dust explosion if, in a mixture with air by the effect of an ignition source of defined energy, it is capable of achieving a self-maintaining level of fire that is connected with an increase in pressure in a closed container (preliminary test with modified Hartmann tube).

Most organic types of dust and many dust mixtures, along with a few inorganic types of dust (for example metal dust of various types) are capable of exploding. [3]

7.2.2 Explosion limits

As there are in areas subject to the danger of gas explosions, so to in areas subject to the danger of dust explosions there are concentration limits within which a mixture of dust and area is capable of exploding. The lower dust explosion limit is determined by a closed pressure vessel approximately in the shape of a ball with an associated control unit. Since the upper dust explosion limit for safety concepts is of little significance, it is generally not specified.

Lower explosion limit LEL: The lower limit of the concentration range within which a mixture of dust and air can be brought to an explosion. [4]

The following are cited as explosion limits:

- Lower explosion limit approx. (20 ... 60) g/m^3
- Upper explosion limit approx. (2 ... 6) kg/m^3.

The range of the lower explosion limit can be clarified by illustrating with two 2 visual experiments:

- At a dust density of 30 g/m^3, a 40-watt light bulb is no longer visible from a distance of 1 m [2];
- Based on measurements of the DMT, with a dust density of approximately 50 g/m^3 there is a loss of 50 % of the light source at a distance of just 5 cm.

More important, however, is the reference that in a room of average height, a layer of dust less than just 1 mm is sufficient to fill the room with a mixture capable of exploding.

7.2.3 Minimum ignition power (MIP)

Minimum ignition power MIP: The lowest amount of energy stored in a condenser as determined using the prescribed experimental conditions that is sufficient upon discharge to ignite a mixture of dust and air capable of exploding and susceptible to ignition. [3]

The minimum amount of energy for various types of dust depends on the concentration of the dust, its granularity, composition (for example humidity, percentage of solvents), the temperature and other factors.

Minimum ignition power levels:

- Readily ignitable dust types (fine aluminium and sulphur dust)
  MIP < 1 mJ
- Readily ignitable dust types (wax dust)
  MIP = (1 ... 10) mJ
- Types of dust moderately susceptible to ignition (sugar, milk powder)
  MIP = (10 ... 100) mJ
- Types of dust that can be ignited only with difficulty (abrasion of types of coal, wheat meal)
  MIP > 100 mJ

VDI report 1272 "Minimum ignition power as an evaluation criterion for selecting protective measures", contains the following classification:

- Types of dust especially susceptible to ignition MIP = (3 ... 10) mJ
- Types of dust extremely susceptible to ignition MIP < 3 mJ [5]

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7.2.4 Median value MV

A significant parameter related to the capacity for explosion is the size of particles. The term used in this connection is the median value. The overall surface increases exponentially as the size of particles decreases. Thus there is more surface for the absorption of air and oxidation with the oxygen in the air. Fine types of dust react more vigorously than coarse types of dust.

The median value is the value for the average granularity (50 % by weight of the dust is coarser and 50 % is finer than the median value). [3]

7.2.5 Explosion pressure, DE dust explosion classes

The maximum (excess) explosion pressure p_{max} is the maximum pressure determined under prescribed experimental conditions that occurs in a closed container upon an explosion of dust mixed with air.

The maximum temporal increase in pressure $(dp/dt)_{max}$ is the highest value determined under the prescribed experimental conditions for the increase in pressure over time that occurs with the explosion of dust in a closed container. [3]

Taking into account that according to the cube law of volume as a function of the maximum increase of pressure over time, it follows that:

$$(dp/dt)_{max} \, . \, V^{1/3} = const = C_{DE} \text{ (in bar.m.s}^{-1}\text{)},$$

Thus the value of C_{DE} is equal to the value of the maximum increase of pressure over time in a 1 m^3 container, i. e. the maximum increase in pressure over time is converted to the C_{DE} value, which is a function of volume. The following classification of types of dust into dust explosion classes is based on the C_{DE} value: [4]

Dust explosion class C_{DE} value in bar · m · s^{-1}

- DE 1 — 0 to 200
- DE 2 — 200 to 300
- DE 3 — greater than 300

7.2.6 Ignition temperature

The ignition temperature of a dust cloud is the lowest temperature of a hot inner wall of an oven at which the ignition of a dust cloud contained in it will occur in air. [6]

When selecting equipment, its surface temperature in accordance with the Declaration of conformity can be a maximum of 2/3 the ignition temperature of the dust cloud.

$$T_{max} = 2/3\, T_{cl},\ T_{cl} = \text{ignition temperature of the dust cloud}$$

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7.2.7 Smoulder temperature

The smoulder temperature of a layer of dust is the lowest temperature of a hot surface at which a layer of dust of specified thickness undergoes combustion on this surface. [6]

It is indicated in DIN EN 61241-1, that 2 different methods are used in determining the maximum surface temperature with a layer of dust.

Method A The maximum surface temperature is determined with a 5 mm thick layer of dust and the installation regulations require a difference of 75 K between the surface temperature and the glow temperature of a particular dust.

Method B The maximum surface temperature is determined with a 12.5 mm thick layer of dust and the installation regulations require a difference of 25 K between the surface temperature and the glow temperature of a particular dust.

For the selection of the apparatus this means that depending on the designation of the apparatus (Ex tD A... or Ex tD B...) its surface temperature must be 75 K (method A) or 25 K (method B) lower than the glow temperature of the particular dust layer concerned.

	Ignition temperature (°C)	Smoulder temperature (°C)
Cotton wool	560	350
Woodmeal	400	300
Cork	470	300
Milk powder	440	340
Strength	440	290
Tobacco	450	300
Sugar beets	460	290
Lignite	380	225
Rubber	460	220
Laminate	510	330
Aluminium	530	280
Bronze	390	260
Iron	310	300
Magnesium	610	410
Soot	620	385
Sulphur	280	280

Table 7.1 Ignition and smoulder temperatures of dust

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7.2.8 Spontaneous combustion temperature

Spontaneous combustion refers to the process in which a material reaches combustion due to the effects of heat on all sides and the presence of air, without any other source of ignition. If the sample exceeds the ambient temperature by more than 60 K, in this process, this is referred to as spontaneous combustion. The spontaneous combustion temperature is one important characteristic value for a safety-related evaluation of drying processes, storage and transport. [4]

Type of dust	D_m µm	T_i °C	T_S °C	T_{SC} °C
Cotton wool	51	380	220	100
Gas coal	28	630	250	100
Activated carbon	23	780	> 400	250
Old wood	45	590	360	190
Clear sludge	31	450	270	140
Animal meal	182	520	> 400	165
Powdered paint	< 20	> 1000	360	180

Table 7.2 Combustion temperature of various types of dust

D_m: Median value
T_i: Ignition temperature of dust that is stirred up
T_s: Smoulder temperature of stored dust (h = 5 mm)
T_{SC}: Spontaneous combustion temperature of stored dust (V = 400 cm^3)

Combustion index

The combustion index (CI) is a criterion for the expansion of a fire based on the local effect of a sufficiently strong source of ignition. [4]

The flammability of stored dust is classified according to the combustion index (CI) which ranges from 1 to 6. CI 1 means "no combustion", while CI 6 means "burning similar to a muffled explosion or rapid decomposition without flames".

Combustion index relative to combustion behaviour

Type of reaction		CI
No expansion of a fire	No scorching	1 Table salt
	Brief ignition and rapid extinguishing	2 Acetic acid
	Local burning or smouldering with extremely minor expansion	3 Milk sugar
Expansion of a fire	Glowing without ejecting sparks (glowing fire) or slow reduction without flames	4 Tobacco
	Burning away with appearance of flames or sparks spreading out	5 Sulphur
	Deflagration-like burning away or rapid decomposition without flames	6 Black powder

Table 7.3 Combustion index relative to combustion behaviour

It should be noted that the combustion index can also change as the ambient temperature increases. For example, while potato starch is not flammable at a normal ambient temperature, at increased temperatures it is highly flammable.

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7.2.9 Protective measures, taking into consideration characteristic values

The following protective measures should be taken, taking into account the characteristic values noted above and additional parameters:

Protective measures	Characteristic values to note
Avoidance of flammable materials	Flammability, capacity to explode, heat from combustion
Limit of concentration/ quantity	Lower explosion limit
Inertisation	Limit concentration of oxygen
Avoidance of ignition sources	Smoulder, ignition and decomposition temperature, spontaneous combustion behaviour, smouldering point, minimum ignition power, sensitivity to impact, electrostatic behaviour
Explosion-proof design for maximum explosion pressure	Maximum explosion pressure
Explosion pressure release	C_{DE} value and maximum explosion pressure
Explosion suppression	C_{DE} value and maximum explosion pressure

Table 7.4 Assignment of characteristic values to protective measures

7.3 Classification of areas subject to the danger of dust explosions into zones

In accordance with appendix 3 of the Industrial Safety Regulation, areas subject to the danger of dust explosions are defined as follows:

Zone 20 is an area in which a dangerous atmosphere capable of exploding is present in the form of a cloud made up of combustible dust that is part of the air permanently, over long periods of time or frequently.

Generally this includes only the inside of containers or equipment, for example the inside of grinding mills, dryers, mixers, conveyor lines and silos, etc. if the conditions of the definition of Zone 20 are met.

Zone 21 is an area in which a dangerous atmosphere capable of exploding may occur occasionally in the form of a cloud made up of combustible dust that is part of the air.

This includes, among others the immediate vicinity of coating openings, the area close to filling and emptying equipment and areas where accumulations of dust are present, which occasionally results in a dangerous atmosphere capable of exploding when they are stirred up.

Zone 22 is an area in which a dangerous atmosphere capable of exploding may occur in the form of a cloud made up of combustible dust that is part of the air. This does not occur normally or is only of brief duration.

This includes areas in the vicinity of systems containing dust if dust can escape from leaks and form accumulations of dust.

IEC 61241-10 – The classification of areas endangered by dust explosion is very similar in concept to that for gas explosion (see EN 60079-10). Taking into account the safety-related characteristic values of different types of dust, important criteria include sources for releasing dust, the possibility of suctioning up dust and the danger of dust accumulation.

In a process for categorising areas subject to the danger of dust explosions (see 4.3 [7]), only the probability of the formation of dust clouds is considered. It is broken down into 3 steps:

1. Identification of material properties (particle size, moisture, minimum temperature of the dust cloud, specific electrical resistance.
2. Determination of where dust is present including containers or sources for releasing dust.
3. Determination of the probability that dust will be released from such sources.

Section 6.3 provides examples of dust atmospheres capable of exploding for the various zones. Practical examples are also treated in an informative appendix, appendix A. In BGR 104 Explosion protection rules Ex-RL (TRBS 2152) there is an extensive compilation of examples.

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7.4 European standards and drafts related to dust explosion protection

In addition to the various standards on methods of investigation, there are the following standards and draft standards, which are of importance to the operator of electrical systems, under the heading of IEC 61214 – Electrical apparatus for use in areas with combustible dust (with the exception of mining operations) (latest revision January 2006 with newly assigned numbers):

IEC 61241-0	General requirements
IEC 61241-1	Protection through housing (ignition protection class "tD")
IEC 61241-2	Protection through excess pressure (on protection class "pD")
IEC 61241-10	Classification of areas in which combustible dust is or could be present.
IEC 61241-11	Protection through intrinsic safety (ignition protection type "iD")
IEC 61241-14	Selecting and setting up
IEC 61241-17	Testing and maintenance
IEC 61241-18	Protection through enclosure (ignition protection type "mD")

At the point in time of the revision of the manual (October 2006) the following standards are available on "Electrical apparatus for use in areas with combustible dust", however, these are currently being replaced by the standards named above:

DIN EN 50281-1-1 (VDE 0170/0171, part 15-1-1): 1999-10
Electrical Equipment with Protection Provided by Housing – Design and Testing

DIN EN 50281-1-2 (VDE 0165, part 2): 1999-11
Electrical Equipment with Protection Provided by Housing – Selection, Set-up and Maintenance

DIN EN 50281-1-2/A1 (VDE 0165, part 2/A1): 2002-11
Electrical Equipment with Protection Provided by Housing – Selection, Set-up and Maintenance

DIN EN 50281-1-1/A1 (VDE 0170/0171, part 15-1-1/A1): 2002-11
Electrical Equipment with Protection Provided by Housing – Design and Testing

DIN EN 50281-3 (VDE 0165, part 102): 2003-05
Categorisation of Hazardous Areas with Explosive Dust Atmospheres

IEC 61241-1: 2004-05	Protection by Housing "tD"
IEC 61241-10: 2004-06	Categorisation of Explosive Dust Atmosphere Areas
IEC 61241-14: 2004-07	Selection and Set-up

Note

No claim is made that this is a complete listing, but it does show that there is currently very intensive activity on the standards relating to protection against dust explosion.

7.5 Overview of the ignition protection categories for dust explosion protection

7.5.1 General requirements (IEC 61241-0)

Since this standard is directed almost exclusively towards the equipment manufacturers, but is still only available in draft form, accordingly only the most important definitions (see also section 7.2) and requirements will be dealt with at this point.

The complete series of standards IEC 61241 has the title "Electrical apparatus for use in areas with combustible dust".

Combustible dust is defined as dust, fibres and airborne debris, which can burn or glow in the air and can form explosive mixtures with air at atmospheric pressure and at normal temperatures.

When selecting a device in accordance with the zone in which the device is to be operated, one selection criterion is the conductivity of the dust.

- Conductive dust is a dust with a specific electrical resistance $\leq 10^3\ \Omega \times m$.

In particular in the case of the ignition protection category "tD" – protection by means of a housing can take different forms:

- A **dust-tight housing** is a housing, which prevents the ingress of dust particles in a visible quantity.
- A **dust protected housing** is a housing, by means of which the ingress of dust is not completely prevented, but is prevented to a degree sufficient to avoid impairment of the safe operation of the apparatus. Dust must not collect in places inside the housing where it could create a risk of ignition taking place.

As distinct from electrical apparatus for use in areas endangered by the risk of gas explosion, where there is an assignment of the apparatus and of the explosive atmosphere to the temperature classes, the apparatus for use in areas with combustible dust must be identified with its maximum surface temperature. In selecting the apparatus, both the ignition temperature of the dust cloud and the glow temperature of the dust layer must be taken into account.

In connection with this problem area the case of ignition protection category "tD" – Protection by housing, is dealt with in detail. Likewise, the matter of determining the identification of the apparatus for the respective ignition protection category is explained.

7.5.2 Ignition protection category "tD" – Protection by housing (IEC61241-1)

This standard replaces DIN EN 50281-1-1, which can be used, however, up to June 01, 2007.

The dust ignition protection category "tD" – protection by housing, embraces all the relevant measures, which are set out in this standard (e. g. protection against the ingress of dust and limitation of surface temperature), which are involved on electrical apparatus with protection by housing in order to prevent the ignition of a dust layer or cloud.

Methods A and B are used in determining the maximum surface temperature of the housing as a function of the presence and the thickness of the dust layer on the housing (see section 7.2.7). The temperature limitations due to the presence of dust layers is dealt with in the treatment in IEC 61241-14 0 – Selection and installation.

For apparatus, whose housings are protected in accordance with method A, a distinction is made between dust-tight and dust-protected housings and their use in Zones 20, 21 and 22 is set out as follows:

- Dust-tight housings in IP6X are to be used in
  - Zone 20,
  - Zone 21,
  - Zone 22 with conductive dust.
- Dust-protected housings in IP5X are to be used in
  - Zone 22 with non-conductive dust.

Examples of identification: Apparatus in ignition protection category "tD", version A, temperature tested with 500 mm thick dust layer for use in Zone 21

- Ex tD A21 IP 65 T225°C T500 320°C

Apparatus in protection category "tD", version B, for use in Zone 22 (for method B it is not necessary to consider the IP rating).

- Ex tD B22 T170°C

7.5.3 Ignition protection category "mD" – Protection through encapsulation (IEC 61241-18)

Encapsulation "mD":

Ignition protection category, in which parts that could ignite an explosive atmosphere either through sparks or through heating, are embedded in a sealing compound in such a way, that neither a dust cloud or a deposit of dust can be ignited under operating or installation conditions.

Electrical devices in the ignition protection category encapsulation "mD" must be grouped either in the protection level "maD" or "mbD".

Devices with the protection level "maD" must not cause an ignition to take place in any of the following cases:

- During normal installation and operating conditions
- Under all specified abnormal conditions
- Under defined fault conditions.

Devices with the protection level "mbD" must not cause an ignition to take place in either of the following cases:

- During normal installation and operating conditions
- Under defined fault conditions.

As regards temperatures, IEC 61241-18 states the following: The maximum surface temperature and the maximum value of the temperature of the sealing compound associated with continuous use must not be exceeded under normal operating conditions.

Example of identification: Apparatus in ignition protection category "mD" for use in Zone 20

- Ex mD 20 T120°C

7.5.4 Ignition protection category "iD" – Intrinsically safe electrical apparatus (E DIN IEC 61241-11)

Intrinsic safety "iD": Ignition protection, which is based on the limitation of electrical energy within an apparatus and the cable and leads used to connect it, which are exposed to the potential explosive atmosphere, to a level below that at which the generation of a spark or heating effects can occur.

Since this draft standard refers in all relevant cases to the intrinsic safety standard for the area endangered by explosive gas, reference will only be made here to the specific peculiarities relating to atmospheres endangered by the risk of dust explosion.

In the section "Categories of electrical apparatus" the remark is made, that electrical apparatus in the category IIA may be suitable.

A reference to the explosion group IIA is also to be found in section 6 – Construction of electrical apparatus:
"Circuits containing intrinsically safe apparatus, which are not in a housing affording limited ingress of dust (i. e. non-insulated intrinsically safe measuring sensor circuits with direct contact with the dust atmosphere threatened by the risk of explosion) must at least be able to satisfy the requirements for spark ignition for electrical apparatus in group IIA."

In both statements consideration is given to the circumstance that the minimum ignition energy of dust is a multiple of that of gases.

For the possibility, that apparatus such as temperature measuring sensors and other monitoring circuits could be completely surrounded by dust, E DIN IEC 61241-11 stipulates:
"All temperatures must be measured or evaluated under the worst fault conditions in the present standard, but however without the application of safety factors for current, voltage or power. The following requirements apply to electrical apparatus, which is used for dust and which has a smouldering temperature of less than 210 °C."

Example identification: Independent intrinsically safe electrical apparatus

- Ex iaD IIIC T4

Associated apparatus

- [Ex ibD] IIIA

Notes: Because of the requirement for the free adaptability of all those devices requiring identification, recognition is given with the mention in this standard of the planned explosion group III.

The highest surface temperature T_A must be identified either with a temperature value, a temperature class or with both.

7.5.5 Ignition protection category "pD" – Pressurised enclosure

Pressurised enclosure "pD": Technology for the use of a protective gas in a housing to prevent the formation of an explosive dust atmosphere by maintaining an overpressure relative to the surrounding atmosphere.

A draft standard for this category of ignition protection has been in existence since 1997, but will not be commented on here.

7.5.6 Installation directions

A few important requirements of EN 50281-1-2 in terms of installation in areas subject to the danger of dust explosions are summarised below:

- Electrical equipment that is covered by a thick layer of dust merits special consideration
- Accumulations of dust greater than 5 mm must be kept separately in system plans and drawings
- Easy accessibility must be provided for testing, maintenance and cleaning
- Protective measures against outside influences must not have any negative effect on normal heat dissipation
- All unused line feed-ins must be closed off by suitable blind stops
- All electrical circuits must be equipped with an effective mechanism for completely disconnecting all lines including the neutral lead, but not the ground lead
- Cable and line systems can be used in all zones that are drawn into screwed, seamlessly drawn or welded tubes or are protected against mechanical damage by their design or are dust-proof
- Reduced requirements apply if lines are laid with protection
- The feed-in of the lead into a piece of equipment must not have any negative effect on the seal of the housing
- If accumulations of dust form on the cables and lines that may prevent free circulation of air, a reduction in the current load capacity should be considered.

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7.6 The installation of electrical systems in areas made hazardous by combustible dust

7.6.1 Selection of electrical apparatus for use in areas with combustible dust

Apparatus for use in Zone 20

In Zone 20, both electrical and non-electrical devices, which are or which contain potential sources of ignition and also protective systems (e. g. armatures with continuous protection against fire and flame barriers) are only permitted for use provided they are identified as follows:

Ex II 1 D

This identification is a binding requirement for all apparatus for use in Zone 0, which has been brought into general use after June 30, 2003.

Up to June 30, 2003 apparatus suitable for Zones 10 or 11 could also be installed in areas endangered by dust explosion.

The use of electrical apparatus suitable for Zone 10, in Zone 20, is permitted if this apparatus has been brought into general use prior to June 30, 2003.

Only electrical apparatus of an approved type of construction could be used in Zone 10, provided its use in Zone 10 is expressly permitted. The apparatus must be subjected to a prototype test and identified accordingly.

Also, the suitability for Zone 10 and all the requisite data for safe use must be stated unequivocally.

However, apparatus, which is suitable for Zone 11, must not be used in Zone 20.

Apparatus for use in Zone 21

In Zone 21, both electrical and non-electrical devices, which are or which contain potential sources of ignition and also protective systems (e. g. armatures with continuous protection against fire and flame barriers) are only permitted for use provided they are identified as follows:

Ex II 2 D

This identification is a binding requirement for all apparatus for use in Zone 21, which has been brought into general use after June 30, 2003.

In addition, apparatus approved for use in Zone 20 can also be used in Zone 21.

Up to June 30, 2003 apparatus suitable for Zones 10 or 11 could also be installed in areas endangered by dust explosion.

The use of electrical apparatus suitable for Zone 10, in Zone 21, is permitted if this apparatus has been brought into general use prior to June 30, 2003.

However, apparatus, which is suitable for Zone 11, must not be used in Zone 21.

Electrical apparatus for use in Zone 22

In Zone 22, both electrical and non-electrical devices, which are or which contain potential sources of ignition and also protective systems (e. g. armatures with continuous protection against fire and flame barriers) are only permitted for use provided they are identified as follows:

Ex II 3 D

This identification is a binding requirement for all apparatus for use in Zone 22, which has been brought into general use after June 30, 2003.

In addition, apparatus approved for use in Zone 20 and 21 can also be used in Zone 22.

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A special factor should be noted in the context of Zone 22, in that in the presence of conductive dust the apparatus in category 2D (with protection category IP6X) must satisfy the requirements for Zone 21 (although in the new draft standards for installation in areas made hazardous by the risk of dust explosion only the protection class IP6X and the category 3D are required).

Up to June 30, 2003 apparatus suitable for Zones 10 or 11 could also be installed in areas endangered by dust explosion.

The use of electrical apparatus suitable for Zone 10 or 11, in Zone 22, is therefore permitted if this apparatus has been brought into general use prior to June 30, 2003. The special requirements for areas endangered by the risk of dust explosion with conductive dust (protection type IP6X) should be noted.

Selection based on glow temperature and ignition temperature

For the selection of electrical apparatus in areas made hazardous by the risk of dust explosion and irrespective of the explosion protection zone, the **Glow temperature** of the deposited dust and the **Ignition temperature** of the explosive dust/air mixture must be known.

The glow temperature is the lowest temperature of a hot surface, at which a dust layer of a given thickness ignites on this hot surface.

The ignition temperature of a dust cloud is defined as the lowest temperature of the hot wall of an oven, at which a dust cloud with air ignites in the oven.

A sub-division, for example into temperature classes, as in the case of areas endangered by gas explosion, does not take place. The maximum surface temperature must be stated on the electrical devices.

The following table provides an overview of the explosion characteristics (ignition temperature, glow temperature and minimum ignition energy) of a number of types of dust.

Substance	$T_{ignition}$ [°C]	T_{Glow} [°C]	ø E_{min} [mJ]
Flour	≥ 380	≥ 300	≥ 30
Wood	≥ 410	≥ 200	≥ 100
Brown coal	≥ 380	≥ 225	–
Pit coal	≥ 500	≥ 240	≥ 1000
PVC	≥ 530	≥ 340	≥ 5
Aluminium	≥ 560	≥ 270	≥ 5
Sulphur	≥ 240	≥ 250	10

Table 7.5 Ignition temperature, glow temperature and minimum ignition energy of types of dust

A point to note, is that a collective term for combustible dust types must be used with caution. For example, flour dust indicates a variety of types of flour, with differing safety characteristics. For example, wheaten flour has quite different characteristics to rye flour.

It is necessary to determine the specific characteristic data of the type of dust contained in each area made hazardous by dust explosion. The use of the characteristic data for dust under a collective term can lead to an incorrect assessment.

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7.6.2 Selection of electrical apparatus (IEC 61241-14) [9]

Permissible apparatus

Permissible apparatus for use in areas with combustible dust is as follows:

1. Dust-tight, non-ignitable housing (Ex tD), housing in accordance with IEC 61241-1
2. Encapsulated apparatus (Ex mD), encapsulated apparatus in accordance with IEC 61241-18
3. Intrinsically safe apparatus (Ex iD) in accordance with IEC 61241-11
4. Pressurised enclosure (Ex pD), pressurised enclosures, which satisfy the requirements for areas made hazardous by the risk of dust explosion in accordance with IEC 61241-2.

Electrical apparatus for Zone 20, 21 and 22 is intended for use under ambient temperatures in the range -20 °C to +40 °C, unless otherwise identified.

Temperature limits

Special attention has to be given to the problem of temperature limitation. Dust layers display two characteristics as the thickness of the layer increases: Reduction of the glow temperature and an increase in the heat insulation.

The maximum permissible surface temperature of the apparatus is determined by deducting a safety margin from the minimum ignition temperature of the dust concerned, which in accordance with the method established in IEC 61241-20-1 has been tested for both dust clouds and dust layers up to a thickness of 5 mm for the ignition protection category "tD", method A, including all other ignition protection categories as well as for a layer thickness of 12.5 mm for ignition protection category "tD", method B, (for methods A and B see section 7.2.7).

Temperature limits due to the presence of dust clouds

The maximum surface temperature of the apparatus must not exceed two thirds of the minimum ignition temperature of the respective dust/air mixture in degrees Celsius:

$T_{max} = 2/3\ T_{CL}$, where T_{CL} is the minimum ignition temperature of the dust cloud.

Temperature limits due to the presence of dust layers

For housings in accordance with method A and all other apparatus the following applies

- up to a layer thickness of 5 mm:
- The maximum surface temperature of the apparatus during the test in a dust-free environment in accordance with IEC 61241-0 must not exceed a value of 75 °C below the glow temperature with a 5 mm thick layer of the respective dust:
- $T_{max} = T_{5\ mm} - 75\ °C$, where $T_{5\ mm}$ is the minimum ignition temperature of the 5 mm thick dust layer (Glow temperature).
- With a layer thickness over 5 mm and up to 50 mm:
- Where there is the possibility that dust layers of over 5 mm may form on housings in accordance with method A, the maximum permissible surface temperature must be reduced. With reference to the following diagram.
- with a layer thickness of over 50 mm, see other requirements in this standard.

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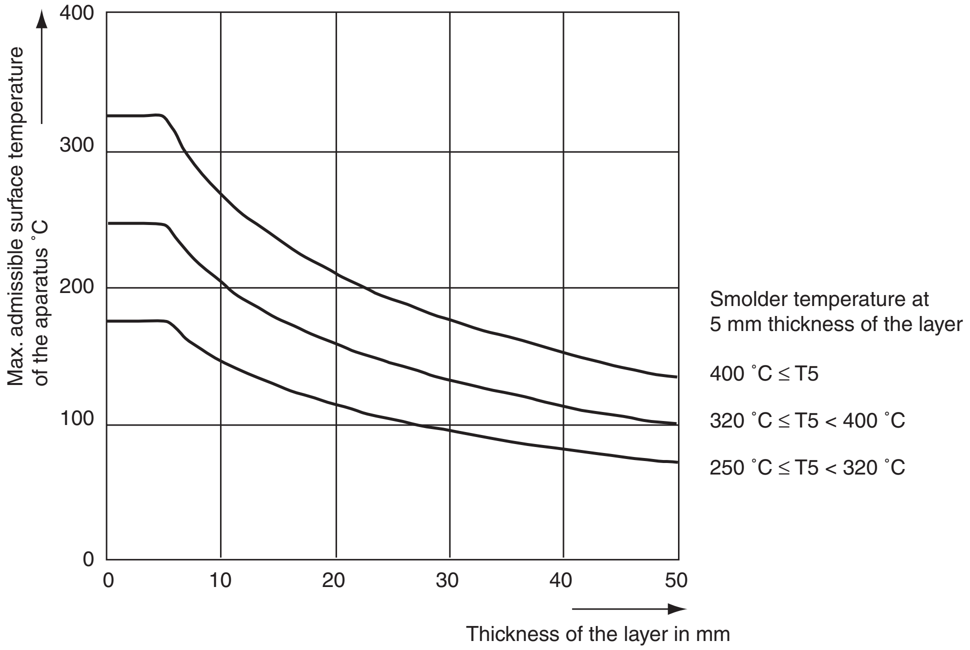

Figure 7.1 Reduction of the maximum permissible surface temperature with increasing layer thickness of the dust deposit

For housings in accordance with method B and for dust layers up to a thickness of 12.5 mm the following applies:

The maximum surface temperature of apparatus must not exceed a value of 25 °C below the glow temperature for a layer thickness of the respective dust of 12.5 mm:

$T_{max} = T_{12.5\,mm}$ - 25 °C, where $T_{12.5\,mm}$ is the glow temperature of a 12.5 mm thick dust layer.

Devices in ignition category "tD" are identified in accordance with ATEX 95 with the equipment group and category and the letter "D" and additionally with the IP-Code and the permissible maximum surface temperature (as well as other information, see [8]). If application in media at different temperatures is envisaged, then accordingly the related permissible surface temperatures are to be stated.

Since a dust deposit cannot arise without the prior occurrence of a dust cloud, the lowest calculated value of the permissible surface temperature as a function of the dust cloud or layer is the decisive factor in the selection of the apparatus.

Condition of the dust	Wheaten flour	Paper	Polyvinyl acetate
Layer	450 °C - 75 K	300 °C - 75 K	340 °C - 75 K
Cloud	2/3 x 480 °C	2/3 x 540 °C	2/3 x 500 °C
Permissible conditions	320 °C	225 °C	265 °C

Table 7.6 Dependence of temperature limits on the type of dust

The following remarks are made in section 10 "Cables and leads" on the problem of the accumulation of dust:

Cable and lead guides should be arranged in such a way, that the smallest possible quantity of dust can collect and that they are accessible for cleaning. If ducts and pipes or recesses are used for the acceptance of cables, precautions should be taken against the ingress and collection of combustible dust in such areas. Where light accumulations of dust form on cables and leads and the free circulation of air is impeded the current carrying capability of the cables may be reduced, in particular in the case of dust having a low minimum ignition temperature.

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Further detailed comments on IEC 61241-14 are dispensed with here, because the stipulations for installation in areas with combustible dust are based very largely on those of IEC 60079-14 for areas endangered by the risk of gas explosion and the additional requirements for the ignition protection categories "iD" and "mD" can be obtained from the apparatus standards.

7.7 References

[1] Chief Eng. Greiner Explosion protection for geared motors (Danfoss Bauer GmbH)

[2] Freytag, H.H. Manual of area explosions

[3] GESTIS-STAUB-EX Database on characteristic values of dust related to fires and explosions (main association of commercial trade unions)

[4] Circular R 003 BGI 747 Safety-related characteristic values (determination and evaluation)

[5] VDI report 1272 Minimum ignition power as an evaluation criterion in selecting protective measures

[6] DIN EN 50281-1-2 Electrical equipment for use in areas with combustible dust part 1-2: Electrical equipment with protection by housing – selection, set-up and maintenance

[7] EN 50281-3 Equipment for use in areas with combustible dust part 3: Classification of areas subject to the danger of dust explosion

[8] DIN EN 50281-1-1 Electrical equipment with protection through housing – construction and testing

[9] DIN EN 61241-14 (VDE 0165-2) Electrical apparatus for use in the presence of combustible dust – part 14: Selection and installation (IEC 61241-14: 2004).

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8 Introduction to non-electrical explosion protection

8.1 Preliminary remarks

The adoption of **Directive 94/9/EC** of the European Parliament and Council of March 23, 1994 for adjusting the legal requirements of member countries for devices and protective systems for proper use in areas subject to the danger of explosion **(ATEX 95)** has laid the groundwork for comprehensive harmonisation of European law in the area of explosion protection.

The fact that this harmonisation also affects non-electrical explosion protection and only became clear much later to many planners, installers, and especially manufacturers of non-electrical devices, equipment and safety, monitoring and control instruments. To make the point more forcefully, the ATEX guideline of May 2000 notes in this regard:
"It should be observed that Directive 94/9/EC specifies for the first time basic health and safety requirements for non-electrical devices intended for use in areas subject to the danger of explosion, for devices intended for use in areas in which there is a danger of explosion due to the formation of dust, for equipment intended for use outside of areas subject to the danger of explosion, and for safe operation of devices and protection systems related to or contributing to the risk of explosion". [1]

In addition to ATEX 95, **ATEX 137** is published as an additional directive and has already been implemented into German law through BetrSichV. However, it does not apply to manufacturers of equipment and will therefore be handled elsewhere.

In addition to the basic safety requirements, ATEX 95 specifies precisely under Chapter II "Procedure for evaluating conformity" which requirements a piece of equipment must meet, who must test it, how it should be assigned to device groups and categories and who may place it in circulation. These very high requirements as they apply to electrical equipment in reference to approval, for example, are not so demanding for non-electrical equipment. While a piece of non-electrical equipment of category 2 normally cannot be placed in circulation without an EC declaration of conformity, "internal manufacturing monitoring" is sufficient for non-electrical equipment of the same category. In contrast to protection systems or electrical equipment, ATEX 95 only requires in a minority of cases that named locations must be involved in the testing of products for non-electrical equipment. Therefore, the target group of the standards for non-electrical explosion-protected equipment is primarily the manufacturer. Only in a very few cases it is the named location.

One other preliminary remark seems important. Although ATEX 95 has already been on the table since 1994 and its implementation in terms of placing equipment in operation is required as of July 1, 2003, with the exception of basic standard DIN EN 13463-1 there is as yet no additional valid European standard for "non-electrical equipment for use in areas subject to the danger of explosion". Along with 3 drafts, there are only working papers and rejected draft versions.
*The reference in the preface of ATEX 95 to the fact that observing the basic requirements of safety and health protection is an absolute necessity and that "they must be implemented with prudence taking into account the state of the art achieved at the point in time when the devices are built", leaves the version open, for placing devices in circulation even without reference to standards. In spite of this, the guideline requires the following: "To facilitate the task of demonstrating that a device meets these requirements, uniform standards must be created on a European level, especially for the **non-electrical area of explosion protection**" [2].*

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The state of standards related to "Non-Electrical Equipment for Use in Hazardous Areas" at the time this manual was revised (February 2005) is as follows:

DIN EN 13463-1: 2002-04
Part 1: Basic Principles and Requirements

DIN EN 13463-5: 2004-03
Part 5: Protection by Safe Design "c"

DIN EN 13463-6: 2005-07
Part 6: Ignition source monitoring "b"

DIN EN 13463-8: 2004-01
Part 8: Protection by Enclosure in Liquid "k"

Draft versions are available for ignition protection types "fr" (flow restricting enclosure), "d" (flameproof enclosure) and "b" (ignition source monitoring).

DIN EN 13463-1 is similar in many ways to EN 50014 of electrical explosion protection, and was in fact initially derived from it. One difference between these two standards is that DIN EN 13463-1 includes all device groups plus usage in areas subject to the danger of dust explosions. Another significant difference is that DIN EN 13463-1 includes a **formalised analysis of ignition hazards**. [3]

The state of the art is represent by these and other standards:

DIN EN 1834-..	Stroke cylinder combustion engines, safety requirements for construction and manufacture of engines for use in areas subject to the danger of explosion.
DIN EN 1755	Safety of front-end loaders
DIN EN 12874	Flash-back safety devices
EN 1010-1	Print and paper processing machinery
VDMA 24169	Directive for ventilators for pumping atmospheres of flammable gases, vapours or mist

8.2 Requirements of ATEX 95

The stipulations of ATEX 95 on device groups and categories, instruction manuals and markings also apply to non-electrical devices (and have been explained in detail elsewhere).

Article 1 of the directive gives the following under area of application:

- "Devices and protection systems for proper use in explosive environments
- Safety, monitoring and control equipment for use outside of areas subject to the danger of explosion, but which are required for safe operation of devices and protection systems in reference to the dangers of explosion.

Examples of affected devices are:

Fans, blowers, compressors, (vacuum) pumps, stirring mechanisms including gear boxes/drive belts, centrifuges, front-end loaders, vibration drives, mechanical mills, and lifting equipment.

The conformity evaluation processes are listed in article 8. It notes the following in reference to non-electrical devices:

"For engines with internal combustion and for electrical devices of Device groups I and II and Device categories M2 and 2, in order for the CE Mark to be affixed, the manufacturer or ...... must apply the process of EC type examination test in accordance with .... the procedure of "conformity with the design" or "quality assurance of products".

For the **remaining devices** of these groups and categories, the manufacturer must apply .... the **procedure of internal manufacturing monitoring** ..... and transfer the documentation materials ..... to a named location which shall immediately confirm receipt of the same and hold them in safekeeping."

In addition, the procedure of EC individual test can be applied.

It is thus clear that the requirements for non-electrical devices are not as extensive. If the design in question is good, hardly any other measures are necessary as part of "internal manufacturing monitoring", at least for devices of category 3.

8.3 Basic principles and requirements for non-electrical devices

Under 1. "Scope of application", DIN EN 13463-1 lists the following standards, which are currently being developed:

prEN 13463-2, *non-electrical devices for use in areas subject to the danger of explosion*

- Protection through drift-inhibiting enclosure (fr)

prEN 13463-3, *non-electrical devices for use in areas subject to the danger of explosion*

- Flameproof enclosure (d).

prEN 13463-4, *non-electrical devices for use in areas subject to the danger of explosion*

- Intrinsic safety (g).

prEN 13463-5, *non-electrical devices for use in areas subject to the danger of explosion*

- Design safety (c).

prEN 13463-6, *non-electrical devices for use in areas subject to the danger of explosion*

- Monitoring of ignition sources (b).

prEN 13463-7, *non-electrical devices for use in areas subject to the danger of explosion*

- Pressurising systems (p).

prEN 13463-8, *non-electrical devices for use in areas subject to the danger of explosion*

- Liquid enclosure (k).

EN 50303, *group I, category M1 devices for use in atmospheres subject to danger of minegas and/or combustible dust*.

The general requirements can be summarised as follows:

- Devices must meet all conditions of application (for example rough handling, the effects of moisture, ambient temperature and fluctuations in pressure, the effect of chemicals, corrosion, and vibration) (see operating instructions);
- Determining and evaluating ignition hazards
  - Device-internal (heat caused by malfunction with ignition hazards internally)
  - Deposits of dust (friction between moving parts)
  - Evaluation of surface temperature based on category
- Documentation of ignition danger evaluation
- Determining the maximum surface temperature for external and internal surfaces (for category 1 the maximum is 80 % of T1 ... T6)

- Prevention of mechanically generated sparks caused by friction, striking and grinding processes (percentages of aluminium, magnesium, titanium, zirconium in alloys and plating limited depending on the category)
- All conducting parts must be connected and grounded to protect against sparks caused by static electricity; dielectric breakdown voltage of non-conducting layers on metal surfaces less than 4 kV; surface resistance less than 109 Ω
- Further detailed requirements depending on device categories and possible sources of ignition.

Following are the maximum permissible percentages by weight for materials of parts exposed to the exterior if there is a risk of ignition caused by friction, striking or sparks caused by rubbing in accordance with the ignition danger evaluation:

- Category 1
  altogether not more than 10 % aluminium, magnesium, titanium and zirconium and altogether not more than 7.5 % magnesium, titanium and zirconium
- Category 2
  not more than 7.5 % magnesium
- Category 3
  no special requirements

Under 5.2 "Evaluation of ignition hazard" the requirement is made that the device and all its parts must be examined according to a formally documented hazard evaluation (for example see appendix B). The result of the evaluation of ignition danger is assignment to the device categories:

"If a device is designed and built in conformity with good engineering practice and the evaluation of ignition hazards ensures that the device will not have any effective ignition source in normal operation, the device can then be assigned to Device category 3.

If it is ensured during the evaluation of ignition hazards that the device does not have any effective ignition sources during foreseeable malfunctions or those that occur infrequently, the device can then be assigned to Device category 2 or Device category 1." [4]

In EN 13463-1, 5.2.7, there is a schematic for the evaluation of the risk of ignition for devices in group II.

Possible ignition sources (1)			**Measures introduced to counter the effectiveness of the ignition source (2)**	**Applied ignition protection (3)**
Normal operation (1a)	**Predictable fault (1b)**	**Seldom occurring fault (1c)**		

Table 8.1 Assessment of the risk of ignition for devices in group II

The columns (1b) and (1c) only need to be completed if, in establishing the device category as group II, it is required that it must be protected from specific faults, e. g. in device category 2 or 1.

The assessment of the risk of ignition must be carried out and documented by the manufacturer of the apparatus. However, the operator of a plant has to undertake the same task, when he has to carry out a risk assessment for the apparatus in the plant, which has not yet had to satisfy the requirements of ATEX 95.

The PTB publishes an extended report schematic on the assessment of the risk of ignition.

Product description																
	1		2					3			4					
	Ignition risk		Assessment of the frequency of occurrence without the application of additional measures					Measures applied to prevent effective ignition			Frequency of occurrence, including measures					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Item. No.	Potential Ignition source	Cause (Under which circumstances does the ignition risk occur?)	during normal operation	during an anticipated fault	in the event of a rare fault	not to be considered	Basis	Description	Background (standards, technical rules, experimental results)	Evidence (including the Ex-relevant characteristics given in column 1)	normal operation	during anticipated fault	during seldom occurring fault	not to be considered	resulting	necessary restrictions
1																
2																
3																
Resulting device category for all existing ignition risks:																

Table 8.2 Evaluation schematic for assessing the ignition risks

This evaluation schematic is used by many named centres, which are only compelled to be active in respect of the prototype testing of devices in category 1.

8.4 Brief characterisation of ignition protection classes for non-electrical devices

Since up to now only 3 standards exist for non-electrical devices and the remainder are in the course of preparation, only a selection of the basic concepts are listed.

For the case, in which a plant operator in the course of preparing an explosion protection document has to carry out a risk assessment on non-electrical apparatus, the application of EN 13463-5 – Protection by constructional safety "c" is recommended. Additionally, the specialist articles that appear in the "atp" or "TÜ", are also recommended [6], [7].

8.4.1 Drift-inhibiting enclosure "fr"

- Ignition protection class which, through operating and design restriction, reduces probability that an atmosphere capable of exploding will penetrate into the housing to an acceptably low level
- Can only be used in areas subject to the danger of gas explosions as category 3 equipment
- Surround potential ignition sources with a sufficiently thick housing so that no atmosphere capable of exploding can come in contact with the ignition source
- Comparable with "drift-safe enclosure".

8.4.2 Flameproof enclosure "d"

- In the case of an ignition inside the enclosure, the housing must resist the pressure. There must be no possibility of a transfer of the "internal" explosion to the outside
- Based in large measure on electrical "flameproof enclosure".

8.4.3 Inherent Safety "g"

- The design includes consideration of the material of possible other objects involved in striking resulting in mechanically generated sparks (sparks from rubbing or striking) and permissible striking energy levels.

8.4.4 Design safety "c".

- Explosion protection class for which the design measures are used to ensure protection against possible inflammation caused by hot surfaces, sparks and adiabatic compression caused by moving parts
- Based on many years of experience
- Probability of a dangerous malfunction is very low
- Considerations of the life of ball and roller bearings; the separation between moving and stationary parts; rotational speeds in excess of 1 m/s; electrostatic problems with belt drives.

8.4.5 Protection through ignition source monitoring "b"

- An arrangement in a non-electrical device, in which one or more sensors built into the device can detect an operating condition, which could possibly cause an ignition of the surrounding atmosphere, and which either automatically or by manual means introduces ignition monitoring precautions, such that the potential ignition source is prevented from being effective.
- Mechanical sensors/actuators are fuse-elements, centrifugal governors, thermostat-valves, pressure relief valves,
- electro-mechanical sensor/actuator systems are used to detect temperature, mass flow, fluid level, speeds, belt stress, etc.

The manufacturer of the non-electrical devices is obliged to obtain the necessary ignition protection level (IPL). [8]

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8.4.6 Pressurising systems "p"

- Displacement of the atmosphere capable of exploding by a protective gas
- Based in large measure to the electrical standard.

8.4.7 Liquid enclosure "k"

Liquid encapsulation is a type of protection, in which the potential ignition sources cannot become active or are separated from the explosive atmosphere, either by complete immersion in a protective liquid or by partial immersion and the permanent wetting of their active surface with a protective liquid, so that an explosive atmosphere, which can find its way over the liquid or outside the device housing, is not ignited. [9]

Examples:

- Immersion pumps
- Hydraulic pumps and engines, liquid couplings
- Gears filled with oil, disk brakes immersed in oil.

8.4.8 Marking

- Basic requirement: The range of application must be recognisable for all ex-related devices, protection systems and components
- II 3 G EEx fr II T4
- II 1 G c/k T4 "/" identifies 2 independent ignition protection classes
- II 2 GD EEx c II 230 °C

8.5 References

[1] ATEX guidelines (first edition, May 2000), guidelines for using directive 94/9/EC

[2] Directive 94/9/EC of March 23, 1994 (ATEX 95)

[3] H. Bothe Physikalisch-Technische Bundesanstalt, Specialist Area 3.3
European standardisation of non-electrical explosion-protected devices

[4] DIN EN 13463-1 Non-electrical devices for use in areas subject to the danger of explosion, part 1: Basic principles and requirements

[5] Dr. Eng. Michael Beyer – Systematic ignition risk assessment of explosion-protected mechanical devices

[6] Matthias Himstedt, Dr. Eng Michael Beyer, TÜ Bd. 45 (2004) No. 5
Explosion-protected stirring/agitating devices, examples of ignition risk assessment.

[7] Cert. Eng. Bernd Kujawski, atp 47 (2005) Vol. 1, ATEX implicit special quality requirements for pneumatic actuators.

[8] EN 13463-6

[9] EN 13463-8

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9 Use of fieldbus systems in an hazardous area

9.1 Preliminary remarks

Fieldbus systems are being used in ever greater numbers in the area of process automation. There are a number of reasons for this:

1. The use of fieldbus systems saves hardware in the form of wiring, cable channels, terminals, input and output cards in the control system or process control system.
2. Field devices with a communication interface have greater functionality that those without a communication interface. They also return diagnostic data in addition to the actual process value. This diagnostic data can be used for a number of purposes including preventive maintenance. Preventive maintenance performed in this manner can reduce downtimes of the system. In addition, it is entirely possible to generate and transfer multiple process values from a single field device. These "intelligent" field devices can be configured and have parameters assigned to them via fieldbus systems. Thus, no additional interface for assigning parameters is needed.
3. System availability can be increased. The reasons for this have already been explained in Item 2.

It must be possible to use such field devices in areas subject to the danger of explosion as well in process automation. Since they must be replaced during ongoing operation in the event of a failure, only Intrinsic Safety Ignition Protection Class need be considered as an ignition protection class.

9.2 Structure of intrinsically safe fieldbus systems

Fieldbus systems are designed as follows according to their working principle:

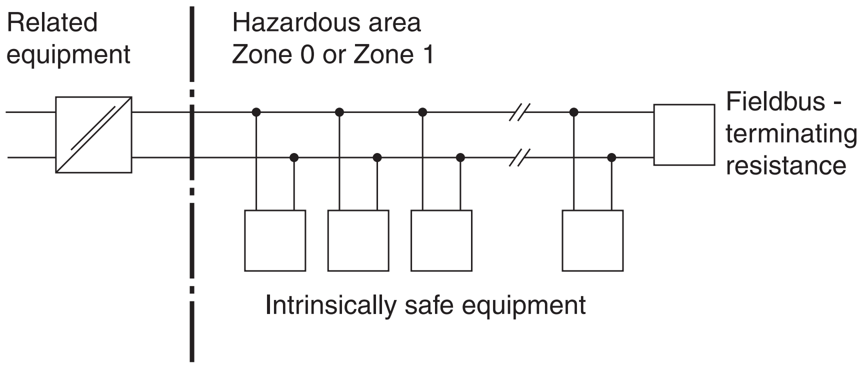

Figure 9.1 Structure of intrinsically safe fieldbus systems

Depending on the fieldbus system in use, the following components may be used as related equipment:

- When using PROFIBUS PA, the **segment coupler** is the related equipment.
- When using the FOUNDATION fieldbus, the **power repeater** is the related equipment.

The field devices used represent the intrinsically safe equipment.

The two fieldbus systems used most frequently in process automation, the PROFIBUS PA and the FOUNDATION fieldbus, use a physical layout that is standardised in IEC 61158-2 for intrinsically safe transfer.

The advantage of this physical layout is that the data and power supply can be transmitted over a common 2-wire channel. The disadvantage is that the transfer rate is very low at 31.25 kBit/s. Especially when remote I/O systems are being used, this results in transfer times that are too long for many applications. Because of this, an intrinsically safe variant, the RS 485 interface, which is also standardised, is very often used in combination with remote I/O systems that are mounted in Zone 1 of an hazardous area.

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9.3 Proof of intrinsic safety for an RS 485 interface

Fieldbus systems generally work according to the master/slave principle. This means that the master sends a telegram that is transferred into the hazardous area by means of the corresponding equipment. The corresponding equipment thus supplies power to the hazardous area and represents a source.

The slave, i. e. the field device or equipment, responds to this telegram. Thus in the event of a response, the slave supplies power to the transfer medium and represents a supply at this point in time.

The result of this is that several sources must be taken into consideration when demonstrating the intrinsic safety on an RS 485 interface. Each field bus station that is not sending receives the running telegram and thus represents a sink. This means that the comparison of voltage, current and power required to demonstrate intrinsic safety must be extended to all conceivable directions of communication:

Related equipment → Field bus station

Field bus station → Related equipment

Field bus station ↔ Field bus station

In this comparison, only the voltages U_o and U_i need to be taken into consideration. The reason why this is so will be explained later.

The comparison of nominal voltage values demonstrates that interconnecting the related equipment with the field devices and interconnecting the field devices with each other is intrinsically safe. It does **not** demonstrate, however, that the same applies to the transfer line. The inductances and capacitances represent the problem in this case. They cannot simply be added together and counted in that manner, since their behaviour and interconnection cannot be unambiguously described in the event of a failure.

In cases such as these, EN 50020 allows for the proof of intrinsic safety to be provided by means of what is referred to as the L/R ratio.

Of course it must first be demonstrated that this procedure is permissible. This process is permissible if:

1. The system under consideration has distributed inductances and capacitances. This is the case here from the point of view of European standards. In the event of a lead break or lead short circuit, the inductance and capacitance of the cable will not be available in concentrated form in a narrowly limited area.
2. Resistive current limiting is present in the related equipment and in each field device.
3. The ratio of the internal capacitance to the maximum capacitance that can be connected for the related equipment and each field device (C_i/C_o) is < 0.01. If the internal capacitance is negligibly low in accordance with the declaration of conformity C_i, the ratio C_i/C_o is also < 0.01.

If these three conditions are met, it has been shown that the proof of intrinsic safety has been provided with the L/R ratio. The declaration of conformity can be referred to for items 2 and 3.

Due to the resistive current limit, only the voltage needs to be taken into consideration when comparing characteristic electrical values, since too high a current is prevented from flowing and the output is prevented from being too great. To reference more information in this regard, see EN 50020 in section 6.3.3.

The next step calculates how high the maximum permissible L/R ratio of the current interconnection can be.

If we assume that L_i is negligibly small as well, the maximum permissible L/R ratio can be calculated according to the following equation:

$$\frac{L}{R}\ (max) = \frac{32 * e * R_i}{9 * U_O^2}$$

where:

- U_o is the maximum output voltage of a field device or related equipment under failure conditions. When the maximum permissible L/R ratio is determined, the most critical case must be assumed for it. This is the case when the highest, most available U_o is applied.
- e is the minimum ignition power in accordance with EN 50020 section 6.3.3, for example 40 µJ for IIC.
- R_i must be calculated. You can do this by dividing the lowest available value of U_o by the greatest conceivable current value. This current is determined from the sum of all I_o that the field devices and the related equipment can return. The reason why currents are added is that the field bus stations are wired in parallel (see figure 9.1) and thus the currents can be added. In this consideration, we proceed from the "worst case" scenario that all components are transmitting simultaneously.

If the maximum permissible L/R ratio is known, the actual L/R ratio must be determined (actual L/R).

This can also be determined from the ratio of the inductance coating to the resistance coating of the cable. The system is intrinsically safe if the condition

$$\frac{L}{R}\ (max) \geq \frac{L}{R}\ (actual)$$

is satisfied.

It should be noted that this proof does not apply to the bus segment under consideration. For other interconnections, the other values are derived from the maximum L/R ratio. For example, if additions are being made to a running system, in addition to comparing the voltages, the maximum permissible L/R ratio must be recalculated, since the maximum conceivable current has changed and with it the maximum permissible L/R ratio as well.

If L_i is not negligibly small for a station, the following equation should be used:

$$\frac{L}{R}\ (max) = \frac{8*e*R_i + \sqrt{64*e^2*R_i^2 - 72*U_o^2*e*L_i}}{4.5 * U_o^2}$$

9.4 The FISCO model

FISCO stands for **F**ieldbus **I**ntrinsically **S**afe **CO**ncept.

The German Federal Physical Technical Institute (PTB) developed the FISCO model and has published it in Report PTB-W-53 "Examination of intrinsic safety for fieldbus systems". This model is based on the following prerequisites:

1. To transmit power and data, the bus system uses the physical configuration defined by IEC 61158-2. This is the case with the PROFIBUS PA and the H1 bus of the FOUNDATION fieldbus, for example. The physical layout is as follows:

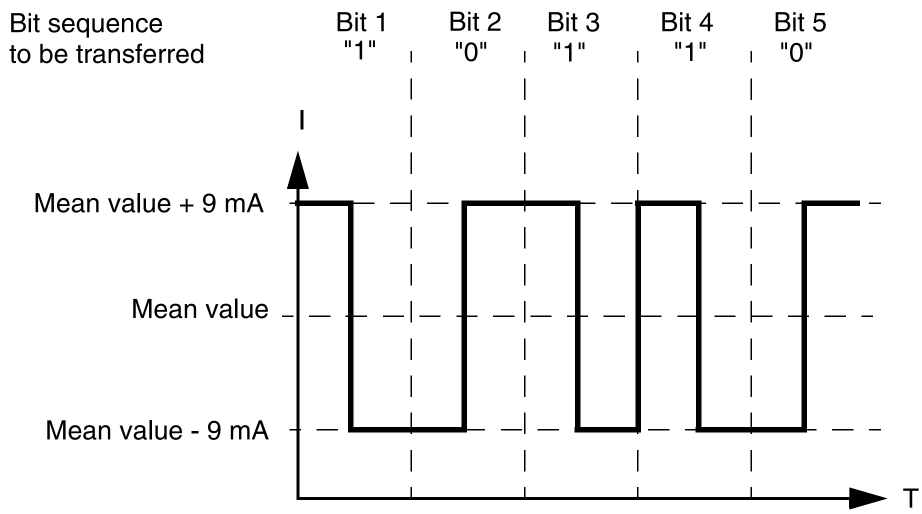

Figure 9.2 Physical layout according to IEC 61158-2

   The data signal is Manchester-coded. This means that a filling edge in the bit midpoint represents a logical "1" and a rising edge in the bit midpoint represents a logical "0". If two equal logical states are entered one after the other as in Fig. 9.2 between Bit 3 and Bit 4, a "compensation edge" must be transferred at the beginning of the following bit. In the example above, this means that a positive edge must be transferred at the beginning of data bit 4. Thus the signal is free of direct current and direct voltage.
   This is a condition required to ensure that the data signal and power supply can be transmitted over the same cable simultaneously. In figure 9.2, the power supply current is represented by the mean value.
2. Only one active sources is permitted on a bus segment (in this case the related equipment, segment coupler or power repeater). All other components work as passive current sinks.
3. The basic current consumption of a bus station is **at least** 10 mA.
   If only one field device is being operated on a piece of related equipment, the field device must draw at least 10 mA of supply current from the transmission line. According to Fig. 9.2, the current increase of the data signal is only ± 9 mA. This means that given unfavourable conditions, a current of 10 mA - 9 mA = 1 mA will be transferred from the related equipment into the hazardous area. Thus power flow will occur only into the hazardous area. This ensures that Item 2 is satisfied.
4. It must be ensured for each field device that

   $U_i \geq U_o$ of the related piece of equipment (segment coupler or power repeater)

   $I_i \geq I_o$ of the related piece of equipment (segment coupler or power repeater)

   $P_i \geq P_o$ of the related piece of equipment (segment coupler or power repeater).

   This comparison must be provided in writing.

5. Each bus station must fulfill the following requirement:
   $C_i \leq 5$ nF
   $L_i \leq 10$ µH

   This is always ensured if a piece of equipment is explicitly certified in accordance with FISCO. In this case, there is a reference on the certificate indicating that the device has been certified in accordance with the FISCO model.
6. The maximum permissible line length for EEx ia IIC applications is **1000 m**. This line length is determined from the length of the main line plus the total of all stub lines.
7. The permissible stub line length for Ex applications is **30 m per stub line.**
8. The transmission line that is used must conform to the following cable parameters:

Resistor coating:	15 Ω/km < R' < 150 Ω/km
inductance coating:	0.4 mH/Km ≤ L' ≤ 1 mH/km
capacitance coating:	80 nF/km ≤ C' ≤ 200 nF/km (including the shield)

   Taking the shield into consideration, the capacitance coating is calculated as follows:
   $C' = C'_{conductor/conductor} + 0.5 * C'_{conductor/shield}$ if the bus line is potential-free
   or
   $C' = C'_{conductor/conductor} + C'_{conductor/shield}$ if the shield is connected with a pole of the related equipment.
9. The bus segment must be terminated on both ends of the line with a terminal bus resistor. A terminating resistor is integrated into the segment coupler or power repeaters so that an external bus termination is only required on the other end. According to the FISCO model, the terminal bus resistance must conform to the following limits:
   $90\ \Omega \leq R \leq 100\ \Omega$
   $0\ \mu F \leq C \leq 2.2\ \mu F$
10. Given the prerequisite that Items 1 to 9 must **all** be satisfied, Proof of Intrinsic Safety has been provided by means of the FISCO model. Items 1, 3 and 5 are automatically satisfied if a product is certified in accordance with the FISCO model. If this is the case, the certificate of the product will explicitly refer to the fact that the product satisfies the requirements according to the FISCO model.

Related equipment according to the FISCO model, such as the segment coupler for PROFIBUS PA and the power repeater for FOUNDATION fieldbus, generally works with an output voltage of 12.8 V and an output current of 100 mA. Since field devices must draw at least 10 mA of supply current from the transmission line in accordance with the FISCO model, theoretically 10 field bus stations can be operated on a piece of related equipment. For many field devices, however, the current consumption is greater than 10 mA. This reduces the number of field devices that can be operated on a bus segment. The number of field devices that can actually be operated depends on the actual current consumption.

9.5 Use of other ignition protection classes in combination with fieldbus systems

If fieldbus systems are designed exclusively to be intrinsically safe, this means that a relatively large number of segment couplers/power repeaters will be required. This was briefly illustrated in the previous chapter. Of course, intrinsically safe equipment has the advantage that it is possible to add or remove elements from the transfer line during ongoing operation. This is only possible with a good deal of effort, usually mechanical, for concepts that rely entirely on other types of ignition protection, which is in turn reflected in the price of the components.

Of course, significantly greater quantities of power can be supplied into the hazardous area for other types of ignition protection than compared to what is possible for the intrinsic safety ignition protection class.

To reduce the amount of material used and combine the advantages of the intrinsic safety ignition protection class with the advantages of other types of ignition protection as well, another concept is available.

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It will be explained below, using PROFIBUS as an example:

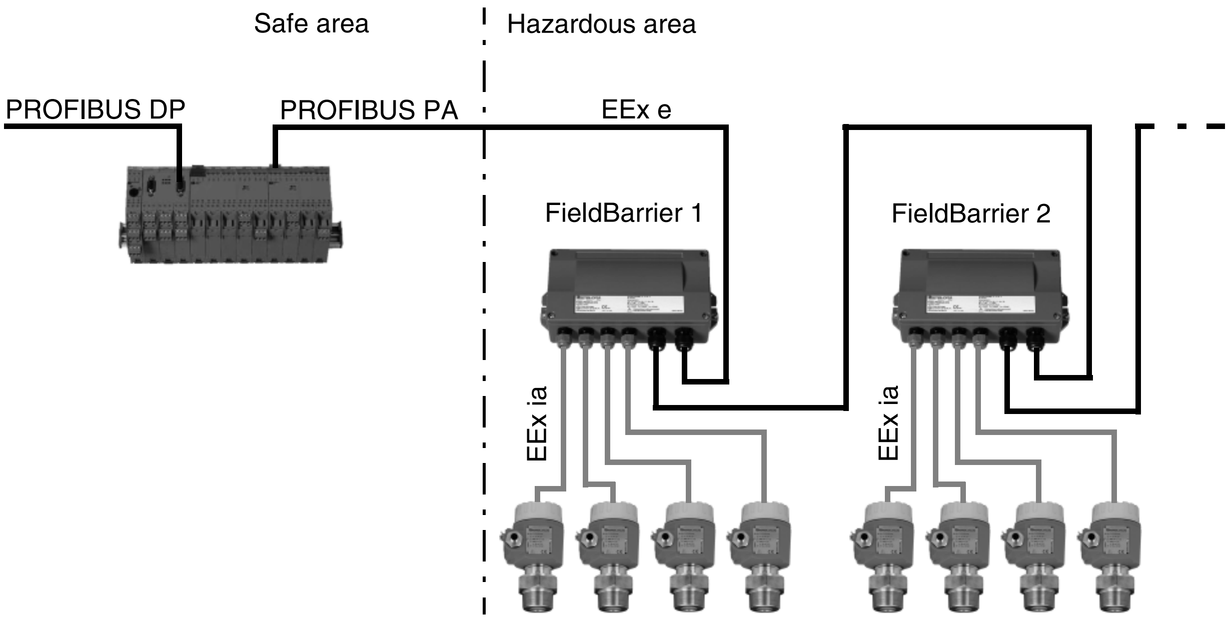

Figure 9.3 The segment coupler forms the interface between the PROFIBUS DP and the PROFIBUS PA

In this case, a segment coupler **without** an intrinsically safe interface is used. Currently this returns up to 400 mA of power supply current for PROFIBUS PA stations. The output line of the segment coupler is designated as the PROFIBUS PA main line, or simply the main line. If the main line is directed into the hazardous area, it will be laid with increased safety (EEx e). Thus, it can only be opened during ongoing operation if a so called fire certificate is present.

Since the field bus segment for the main line is a non-intrinsically safe field bus segment, it can be up to 1900 m long. Furthermore, non-intrinsically safe segment couplers work at an output voltage of at least 24 V.

A conversion takes place locally in the FieldBarrier from a non-intrinsically safe field bus segment to up to 4 intrinsically safe outputs to which the field devices can be connected. The FieldBarrier may be mounted in Zone 1 of an hazardous area. The electronics of the FieldBarrier is inside a cast enclosure. EEx e terminals are available for the connections to the main line.

40 mA of power supply current is available for the field devices. This is sufficient to provide power to PROFIBUS PA field devices via the fieldbus line that are also intrinsically safe, which have a significantly greater current consumption than 10 mA.

The output currents and the power supply current of the FieldBarrier itself are derived from the main line. The maximum line length per intrinsically safe output is 120 m and is operated without a terminating fieldbus resistor. The intrinsically safe outputs of the FieldBarrier are certified in accordance with the FISCO model.

The advantage of this fieldbus structure is that fewer PROFIBUS PA segments and thus fewer segment couplers are required. In addition, the FieldBarriers replace distributor boxes, which would otherwise be required. Each output of the FieldBarrier is galvanically isolated from the main line and has short circuit current limiting.

If a short circuit occurs in a "normal" fieldbus application between the transfer lines, the entire fieldbus segment fails. This is prevented by a combination of short circuit current limiting and galvanic isolation. This arrangement also prevents a fault on one of the FieldBarrier outputs from having an effect on the other outputs (absence of reverse effect). Because of this, a short circuit causes only the fieldbus that is connected to the output in question to fail. This in turn increases the availability of the system.

This concept can be used with the FieldBarrier for a FOUNDATION fieldbus as well. In the case of the FOUNDATION fieldbus, non-intrinsically safe power repeaters with a maximum output current of 400 mA and an output voltage of 24 V or power conditioners with an output current of up to 1 A and output voltage of 31 V are used as power supply devices.

9.6 Shielding of an intrinsically safe fieldbus application

Shielded cables should be used as a field bus transfer line. Appropriate cables for this purpose are recommended in the installation guidelines of individual fieldbus systems. In order for the shield to perform its task of protecting against electromagnetic interference, it must be grounded.

There are 3 possibilities:

1. The shield is connected on one side with potential equalisation, i. e. it is hard grounded.
2. The shield is hard grounded on one side, while the other end of the shield is connected with potential equalisation via a capacitor (capacitive grounding).
3. The shield is hard grounded on both sides.

If Version 1 is selected, there is no problem from the point of view of explosion protection, since no equalisation currents can flow through the shield. It may happen, however, that the EMC protection is not sufficient in this version.

Version 2 offers better protection. In this case, the shield is typically connected directly with the potential equalisation (hard grounding to the field devices). The shield on the corresponding equipment is connected to the potential equalisation via a capacitor.

High-frequency EMC interference pulses are directed away on both ends of the line, thus via the capacitor as well. This results in better EMC protection than with version 1.

Since the capacitor must be mounted in the safe area for this version, but it is also connected with a shield that is laid in the hazardous area, it must satisfy certain requirements. It must

- have a fixed dielectric (for example ceramic),
- have a capacitance $C \leq 10$ nF,
- be designed for a test voltage between shield and data line ≥ 1500 V.

However, the best EMC protection is achieved if the shield is connected directly with potential equalisation on both sides.

This potential equalisation entails a not insignificant amount of effort in practical cases. For example, installation requirements as they are explained in chapter 5 of this manual must be taken into consideration.

Only the user can decide what kind of EMC protection is actually required in the systems in question. In systems with low "EMC contamination" it may be sufficient to select the first of the three possibilities. In systems with very heavy "EMC contamination", it may be necessary to use version 3.

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10 List of key words

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P

R

S

T

V

Z

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13 Appendix

13.1 Marking of firedamp-protected and explosion-protected electrical equipment in accordance with VDE 0171/V.43

Requirements for firedamp-protected electrical equipment	VDE 0170/V.43
Requirements for explosion-protected electrical equipment	VDE 0170/V.43

Layout of abbreviations for firedamp protection (Sch)			
General identifying letter for Firedamp protection		Sch	
Letter for Protection class	Flameproof enclosure Plate protection enclosure Oil enclosure External ventilation Increased fuse Special protection type		d p o f e s
(Sch) with plate protection enclosure p			

Table 13.1 Structure of abbreviation for firedamp protection

Layout of abbreviations for explosion protection (Ex)					
General identifying letter for Explosion protection		Ex			
Letter for Protection class	Flameproof enclosure Oil enclosure External ventilation Increased fuse Special protection type		d o f e s		
Letter for Ignition group	Ignition temperature (determination according to VDE 0173) over 450 °C over 300 °C over 175 °C over 120 °C			A B C D	
Number for Explosion group*	Gap width, at which an ignition dielectric breakdown occurred at 25 mm gap length (determination based on VDE 0173) over 0.8 mm over 0.5 to 0.8 mm 0.5 mm				1 2 3
Examples of abbreviations	Protection class flameproof enclosure for benzene	Ex	d	A	
	Protection class flameproof enclosure for ethyl ether	Ex	d	C	1
	Protection class oil enclosure for carbon disulphide	Ex	o	D	1
	Protection class increased safety for acetylene	Ex	e	B	

* for flameproof enclosure d only

Table 13.2 Structure of abbreviation for explosion protection

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PEPPERL+FUCHS

13.2 Marking of firedamp-protected and explosion-protected electrical equipment in accordance with VDE 0170/0171 b/9.57

Requirements for firedamp-protected and explosion-protected electrical equipment	VDE 0170b/9.57 and VDE 0171b/9.57

Layout of abbreviations for firedamp protection and explosion protection							
					Protection class	Explosion class	Ignition group
General abbreviation: for firedamp protection for explosion protection			Sch	Ex			
Abbreviation for Protection class	Flameproof enclosure Plate protection enclosure Oil enclosure External ventilation Increased fuse Special protection type				d p o f e s		
Abbreviation for explosion class*	Gap width at which an ignition dielectric breakdown 25 mm occurred at gap length (determination based on VDE 0173) New version	above 0.6 mm over 0.4 to 0.6 mm 0.5 mm 0.4 mm and less				1 2 3a 3b 3c ... 3n	
Abbreviation for Ignition group	Ignition temperature in °C (determination based on VDE 0173) New version	over 450 over 300 to 450 over 200 to 300 over 135 to 200 from 100 to 135					G1 G2 G3 G4 G5

* for flameproof enclosure d only

Table 13.3 Structure of abbreviation for firedamp and explosion protection

13.3 Marking of firedamp-protected and explosion-protected electrical equipment; comparison and contrast of marking in accordance with VDE 0170/0172 2.65 to VDE 0170/0171 5.78

Symbol EEx	Application old	Application new	Ignition protection class old	Ignition protection class new	Explosion class new	Explosion group new	Ignition group old	Temperature class new
Firedamp protection	(Sch)	I				II		
Explosion protection	(Ex)	II						
Plate protection enclosure [only (Sch)]			p					
Pressurising systems, external ventilation (old)			f	p				
Oil enclosure			o	o				
Flameproof enclosure			d	d				
Sand enclosure				q				
Increased safety			e	e				
Special protection, cast enclosure			s	m				
Intrinsic safety			i	ia				
				ib				
Maximum permitted gap (old)	> 0.6 mm				1			
Applies only	> 0.4 ... 0.6 mm				2			
for (Ex) d	≤ 0.4 mm				3a ... 3n			
MESG: Maximum permitted gap (for EEx d)	MESG		MIC					
MIC: Minimum ignition current ration	> 0.9 mm		> 0.8			IIA		
to laboratory methane	0.5 ... 0.9 mm		0.45 ... 0.8			IIB		
(for EEx i)	< 0.5 mm		< 0.45			IIC		
Ignition temperature of flammable materials (°C)	Max. surface temperature of equipment (°C)				Ignition group based on VDE 0170/0171/05.43			
> 450	450				A		G1	T1
> 300	300				B		G2	T2
> 200	200				C		G3	T3
> 135	135				C		G4	T4
> 100	100				D		G5	T5
> 85	85				-		G6	T6

Table 13.4 Comparison and contrast of marking of firedamp-protected and explosion-protected electrical equipment

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13.4 Marking of explosion-protected electrical equipment in accordance with DIN EN 50014 (VDE 0170/0171, part 1) 2.2000

A permanently legible marking must contain, in addition to the manufacturer's name or trade-mark and type code, the following information:

Marking also includes issuing of a test certificate and naming the test location and certificate number.

Ex EEx de II C T6

- the EEx symbol
- the abbreviation of the ignition protection class used
- the symbol for the group of electrical equipment
- the symbol for the temperature class or the highest surface temperature in °C (for group II)

Marking also includes issuing of a test certificate and naming the test location and certificate number.

Identification of electrical equipment with certificate of conformity of an EC test location

E: built to European standard

Ex: explosion-protected equipment

Ignition protection type used

o: oil enclosure
p: pressurising system
q: sand enclosure
d: flameproof enclosure
e: increased safety
i: intrinsic safety
m: cast enclosure
SYST: intrinsically safe systems

All ignition protection classes used for a piece of equipment must be specified after the main ignition protection class.
In the example above:
Main ignition protection class "d"
Secondary ignition protection class "e"

n: non incendive

Range of application

I: mines susceptible to firedamp

II: all potentially explosive atmospheres exceptmines susceptible to firedamp

Sub-division of group II into IIA, IIB, IIC only for

flameproof enclosure "d"	Intrinsic safety "i"	
Maximum permitted gap	Minimum ignition current ratio MIC	MIC
A = > 0.9 mm	Ratio index related to methane	A = > 0.8
B = > 0.5 mm...0.9 mm		B = 0.45 ... 0.8
C = < 0.5 mm		C = < 0.45

Temperature class	Max. surface temperature [°C]	Ignition temperature of flammable materials [°C]
T1	450	> 450
T2	300	> 300
T3	200	> 200
T4	135	> 135
T5	100	> 100
T6	85	> 85

at an ambient temperature range outside (-20 °C ... +40 °C), additional marking with T_a or T_{amb}.

Table 13.5 Marking of electrical equipment

13.5 Marking of devices and protective systems in accordance with appendix II of Directive 94/9/EC (ATEX 95)

The following minimum outputs must be clearly and indelibly affixed on each device and protective system:

- Name and address of the manufacturer
- CE-Marking
- Designation of series and type
- Serial number, if applicable
- Year of manufacture
- The special identification for protection from explosions ⟨Ex⟩ in connection with the identification that refers to the category
- for Device group II or letter "G" (for areas in which mixtures of gas, vapour, mist and air capable of exploding are present)* and/or the letter "D" (for areas in which dust is capable of forming a potentially explosive atmosphere).**

In addition, and if necessary, all notices that are essential for safety during use must also be affixed.

Examples

* Equipment for Zone 1 ⟨Ex⟩ II 2 G

** Equipment for Zone 1 ⟨Ex⟩ II 1 D

13.6 General requirements for explosion protection

<table>
<tr><th></th><th>European Union</th><th>North America</th></tr>
<tr><td>Division of hazards</td><td>Mixtures capable of explosion in
Group I: mines susceptible to firedamp
Group II: other areas outside of mines</td><td>Explosive mixtures of air with
CLASS I: gases and vapours
CLASS II: dust
CLASS III: fibres</td></tr>
<tr><td>Ignition hazards due to sparks</td><td>Sub-division for ignition protection classes
Intrinsic safety/flameproof enclosure based on minimum ignition current/maximum permitted gap, assigning minimum ignition power of representative gases:
Group I methane
Group IIA propane
Group IIB ethylene
Group IIC hydrogen, acetylene</td><td>Sub-division of class based on ignition power:
CLASS I Group
A Acetylene
B Hydrogen
C Ethylene
D Methane
CLASS II Group
E Metallic dust
F Coal dust
G Grain dust
CLASS III No grouping</td></tr>
<tr><td>Ignition hazards due to hot surfaces</td><td colspan="2">Division into temperature classifications to IEC 79-8 for maximum surface temperatures at an ambient temperature of 40°C under failure conditions:
T1 < 450 °C, T2 < 300 °C, T3 < 200 °C, T4 < 135 °C, T5 < 100 °C, T6 < 85 °C</td></tr>
<tr><td rowspan="3">Classification of hazardous areas</td><td colspan="2">According to probability of occurrence of a hazardous atmosphere capable of explosion, subdivision as follows:</td></tr>
<tr><td>for gases, vapours and mist:
Zone 0 constant or long term
1 occasional
2 seldom and short term
for dust:
Zone 20 constant long term or frequent
21 occasional
22 none or short term</td><td>for gases and dust:
Division 1
Division 1
Division 2</td></tr>
<tr><td colspan="2">Note (see IEC 79-10): constant or long term corresponds to > 1000 h/year, occasional corresponds to 10 ... 1000 h/year, seldom or short term corresponds to < 10 h/year</td></tr>
<tr><td rowspan="2">Safety-related characteristic values</td><td colspan="2">Regarding characteristic values for flammable gases and vapours as a basis for grouping according to ignition power and temperature as well as flash point, see:</td></tr>
<tr><td>DIN EN 50014: 1997 appendix A
BS 5345, part 1</td><td>NFPA 497 M
CSA No. C22-1</td></tr>
<tr><td>Approval sites
(named locations in accordance with Directive 94/9/EC)</td><td>PTB German Federal Physical/ Technical Institute (Physikalisch-Technische Bundesanstalt)
DMT Deutsche Montan Technologie GmbH
EXAM BBG Prüf- und Zertifizier GmbH
BASEEFA British Approvals Service for Electrical Equipment in Flammable Atmosphere
TÜV TÜVNord Cert GmnH & Co. KG
and others</td><td>UL Underwriters Laboratories, USA
FM Factory Mutual Research, USA
CSA Canadian Standards Association</td></tr>
<tr><td>Installation requirements</td><td>EN 60079-14
DIN EN 50281-1-2 (for dust)
EN 60079-10
and other EC-wide and national (for example ExVo) requirements)</td><td>NFPA 70
National Electrical Code Art. 500
NFPA 493
Standard for Intrinsically safe operations...
NFPA 70
National Electrical Code Art. 505</td></tr>
</table>

Table 13.6 General requirements for explosion protection

13.7 Important internet addresses

Beuth-Verlag	http://www.beuth.de
BG Chemie	http://www.bgchemie.de
Trade Association Institute for Work Safety	http://www.hvbg.de/d/bia
Physikalisch- technischen Bundesanstalt	http://www.explosionsschutz.ptb.de
DIN	http://www.din.de
DKE	http://www.dke.de
CENELEC	http://www.cenelec.org
IEC	http://www.iec.ch
IECEx	http://www.iecex.com
Accident prevention requirements	http://www.bc-verlag.de/uvven
European directives	http://www.europa.eu.int/eur-lex/de

Internet addresses for more extensive information (source: Deutsche Montan Technologie GmbH)

Directives for the new concept in general
http://www.newapproach.org/directiveList.asp

Directives for the new concept, information page of the directorate general of companies
http://europa.eu.int/comm/enterprise/newapproach/standardization/info.html

All directives for the new concept, including EMC directive,
European and lists of harmonised standards on the directive of the new concept, European
http://europa.eu.int/comm/enterprise/newapproach/standardization/harmstds/reflist.html

More extensive information, for example manuals or similar information
http://europa.eu.int/comm/enterprise/newapproach/standardization/publicat.html

Directive 94/9/EC and directive 98/37/EC, etc.; special pages for the directorate general of companies
http://europa.eu.int/comm/enterprise/policy_en.htm

ATEX directives
http://europa.eu.int/comm/enterprise/atex/index.htm

Electrical devices, i. e. low-voltage directive, EMC and directive on electromagnetic environmental effects
http://europa.eu.int/comm/enterprise/electr_equipment/index.htm

Machine devices, i. e. machine directive, elevator directive and personal protective equipment
http://europa.eu.int/comm/enterprise/mechan_equipment/index.htm

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13.8 Directive 94/9/EC of the European Parliament and Council of March 23, 1994 for harmonising statutory requirements of member nations for devices and protection systems intended for use in areas subject to the danger of explosion (ATEX 95)

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I

(Acts whose publication is obligatory)

DIRECTIVE 94/9/EC OF THE EUROPEAN PARLIAMENT AND THE COUNCIL

of 23 March 1994

on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 100a thereof,

Having regard to the proposal from the Commission ([1]),

Having regard to the opinion of the Economic and Social Committee ([2]),

Acting in accordance with the procedure referred to in Article 189b of the Treaty establishing the European Community,

Whereas it is the duty of Member States to protect, on their territory, the safety and health of persons and, where appropriate, domestic animals and property and, in particular, that of workers, especially against the hazards resulting from the use of equipment and systems providing protection against potentially explosive atmospheres;

Whereas mandatory provisions within the Member States determine the level of safety to be achieved by protective equipment and systems intended for use in potentially explosive atmospheres; whereas these are generally electrical and non-electrical specifications having an effect on the design and structure of equipment which can be used in potentially explosive atmospheres;

Whereas the requirements to be met by such equipment differ from one Member State to another in respect of their extent and differing inspection procedures; whereas these differences are, therefore, likely to raise barriers to trade within the Community;

Whereas harmonization of national legislation is the only way in which to remove these barriers to free trade; whereas this objective cannot be satisfactorily achieved by the individual Member States; whereas this Directive merely lays down the requirements vital to freedom of movement for the equipment to which it applies;

Whereas the regulations intended to remove technical barriers to trade are required to follow the new approach provided for in the Council resolution of 7 May 1985 ([3]), which requires a definition of the essential requirements regarding safety and other requirements of society without reducing existing, justified levels of protection within the Member States; whereas that resolution provides that a very large number of products be covered by a single Directive in order to avoid frequent amendments and the proliferation of Directives;

Whereas the existing Directives on the approximation of the laws of the Member States to electrical equipment for use in potentially explosive atmospheres have made positive steps towards protection against explosions via measures linked with the structure of the equipment at issue and which have helped to remove barriers to trade in this area; whereas, in parallel, a revision and expansion of the existing Directives is necessary since, more particularly, in an overall context, action must be taken to guard against the potential hazards arising from such equipment. This implies in particular that measures intended to guarantee effective protection of users and third parties must already be contemplated at the design and manufacturing states;

Whereas the form taken by the hazard, the protective measures and the test methods are often very similar, if not identical, for both mining and surface equipment; whereas it is, therefore, absolutely necessary to cover by a single Directive protective equipment and systems falling within both groups;

Whereas the two groups of equipment referred to above are used in a large number of commercial and industrial sectors and possess considerable economic significance;

Whereas compliance with the basic safety and health requirements is essential in order to ensure the safety of

([1]) OJ No C 46, 20. 2. 1992, p. 19.
([2]) OJ No C 106, 27. 4. 1992, p. 9.
([3]) OJ No C 136, 4. 6. 1985, p. 1.

protective equipment and systems; whereas those requirements have been subdivided into general and additional requirements which must be met by protective equipment and systems; whereas, in particular, the additional requirements are intended to take account of existing or potential hazards; whereas protective equipment and systems will, therefore, embody at least one of those requirements where this is necessary for their proper functioning or is to apply to their intended use; whereas the notion of intended use is of prime importance for the explosion-proofing of protective equipment and systems; whereas it is essential that manufacturers supply full information; whereas specific, clear marking of said equipment, stating its use in a potentially explosive atmosphere, is also necessary;

Whereas the intention is to prepare a Directive on operations in potentially explosive atmospheres which is based on Article 118a; whereas that additional Directive will, in particular, aim at explosion hazards which derive from a given use and/or types and methods of installation;

Whereas compliance with essential health and safety requirements is imperative if the safety of equipment is to be ensured; whereas judgment will have to be exercised in the implementation of those requirements in order to take account of both the technology obtaining at the time of manufacture and overriding technical and economic requirements;

Whereas, therefore, this Directive sets out essential requirements only; whereas, in order to facilitate the task of proving compliance with the essential requirements, harmonized European standards are necessary, more especially with regard to the non-electrical aspects of protection against explosions — standards relating to the design, manufacture and testing of equipment, compliance with which enables a product to be presumed to meet such essential requirements; whereas harmonized European standards are drawn up by private bodies and must retain their non-mandatory status; whereas, for this purpose, the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (Cenelec) are recognized as the bodies competent to adopt harmonized standards which follow the general guidelines for cooperation between the Commission and those two bodies, signed on 13 November 1984; whereas, for the purposes of this Directive, a harmonized standard is a technical specification (European Standard or harmonization document) adopted by one or other of those bodies, or by both, at the prompting of the Commission pursuant to Council Directive 83/189/EEC of the 28 March 1983 providing for a procedure governing the provision of information on technical standards and regulations (1) and pursuant to the general guidelines referred to above;

(1) OJ No L 109, 26. 4. 1983, p. 8. Directive as last amended by Directive 88/182/EEC (OJ No L 81, 26. 3. 1988, p. 75).

Whereas the legislative framework should be improved in order to ensure that employers and workers make an effective and appropriate contribution towards the standardization process; whereas this should be completed by the time this Directive is implemented;

Whereas, in view of the nature of the risks involved in the use of equipment in potentially explosive atmospheres it is necessary to establish procedures applying to the assessment of compliance with the basic requirements of the Directives; whereas these procedures must be devised in the light of the level of risk which may be inherent in equipment and/or against which systems must protect the immediate environment; whereas, therefore, each category of equipment conformity must be supplemented by an adequate procedure or a choice between several equivalent procedures; whereas the procedures adopted comply fully with Council Decision 93/465/EEC of 22 July 1993 concerning the modules for the various phases of the conformity assessment procedures which are intended to be used in the technical harmonization Directives (2);

Whereas the Council has provided for the affixing of the CE marking by either the manufacturer or his authorized representative within the Community; whereas that marking means that the product complies with all the basic requirements and assessment procedures provided for by the Community law applying to that product;

Whereas it is appropriate that the Member States, as provided for by Article 100a of the Treaty, may take temporary measures to limit or prohibit the placing on the market and the use of equipment and protective systems in cases where they present a particular risk to the safety of persons and, where appropriate, domestic animals or property, provided that the measures are subject to a Community control procedure;

Whereas the recipients of any decision taken as part of this Directive must be aware of the reasons behind that decision and the means of appeal open to them;

Whereas, on 18 December 1985, the Council adopted a framework Directive on electrical equipment for use in potentially explosive atmospheres (76/117/EEC) (3) and, on 15 February 1982, a Directive concerning electrical equipment for use in potentially explosive atmospheres in mines susceptible to fire damp (82/130/EEC) (4); whereas, from the outset of harmonization work, the conversion into total harmonization of the optional and partial harmonization on which these Directives are based had been contemplated; whereas this Directive fully covers the

(2) OJ No L 220, 30. 8. 1993, p. 23.
(3) OJ No L 24, 31. 1. 1976, p. 45. Directive as last amended by Directive 90/487/EEC (OJ No L 270, 2. 10. 1990, p. 23).
(4) OJ No L 59, 2. 3. 1982, p. 10.

scope of the abovementioned Directives and whereas, therefore, these Directives must be repealed;

Whereas the internal market incorporates an area without internal frontiers within which the free movement of goods, persons, services and capital is assured;

Whereas it is necessary to provide for a transitional arrangement enabling equipment manufactured in compliance with the national regulations in force at the date of adoption of this Directive to be marketed and placed in service,

HAVE ADOPTED THIS DIRECTIVE:

CHAPTER I

Scope, placing on the market and freedom of movement

Article 1

1. This Directive applies to equipment and protective systems intended for use in potentially explosive atmospheres.

2. Safety devices, controlling devices and regulating devices intended for use outside potentially explosive atmospheres but required for or contributing to the safe functioning of equipment and protective systems with respect to the risks of explosion are also covered by the scope of this Directive.

3. For the purposes of this Directive, the following definitions shall apply:

Equipment and protective systems intended for use in potentially explosive atmospheres

(a) 'Equipment' means machines, apparatus, fixed or mobile devices, control components and instrumentation thereof and detection or prevention systems which, separately or jointly, are intended for the generation, transfer, storage, measurement, control and conversion of energy for the processing of material and which are capable of causing an explosion through their own potential sources of ignition.

(b) 'Protective systems' means design units which are intended to halt incipient explosions immediately and/or to limit the effective range of explosion flames and explosion pressures. Protective systems may be integrated into equipment or separately placed on the market for use as autonomous systems.

(c) 'Components' means any item essential to the safe functioning of equipment and protective systems but with no autonomous function.

Explosive atmospheres

Mixture with air, under atmospheric conditions, of flammable substances in the form of gases, vapours, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture.

Potentially explosive atmosphere

An atmosphere which could become explosive due to local and operational conditions.

Equipment groups and categories

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

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

The categories of equipment defining the required levels of protection are described in Annex I.

Equipment and protective systems may be designed for a particular explosive atmosphere. In this case, they must be marked accordingly.

Intended use

The use of equipment, protective systems, and devices referred to in Article 1 (2) in accordance with the equipment group and category and with all the information supplied by the manufacturer which is required for the safe functioning of equipment, protective systems and devices.

4. The following are excluded from the scope of this Directive:

— medical devices intended for use in a medical environment,

— equipment and protective systems where the explosion hazard results exclusively from the presence of explosive substances or unstable chemical substances,

— equipment intended for use in domestic and non-commercial environments where potentially explosive atmospheres may only rarely be created, solely as a result of the accidental leakage of fuel gas,

— personal protective equipment covered by Directive 89/686/EEC [1],

— seagoing vessels and mobile offshore units together with equipment on board such vessels or units,

[1] OJ No L 399, 30. 12. 1989, p. 18.

— means of transport, i.e. vehicles and their trailers intended solely for transporting passengers by air or by road, rail or water networks, as well as means of transport in so far as such means are designed for transporting goods by air, by public road or rail networks or by water. Vehicles intended for use in a potentially explosive atmosphere shall not be excluded,

— the equipment covered by Article 223 (1) (b) of the Treaty.

Article 2

1. Member States shall take all appropriate measures to ensure that the equipment, protective systems and devices referred to in Article 1 (2) to which this Directive applies may be placed on the market and put into service only if, when properly installed and maintained and used for their intended purpose, they do not endanger the health and safety of persons and, where appropriate, domestic animals or property.

2. The provisions of this Directive shall not affect Member States' entitlement to lay down, in due observance of the provisions of the Treaty, such requirements as they may deem necessary to ensure that persons and, in particular, workers are protected when using the equipment, protective systems, and devices referred to in Article 1 (2) in question provided that this does not mean that such equipment, protective systems, or devices are modified in a way not specified in the Directive.

3. At trade fairs, exhibitions, demonstrations, etc., Member States shall not prevent the showing of equipment, protective systems, or the devices referred to in Article 1 (2) which do not conform to the provisions of this Directive, provided that a visible sign clearly indicates that such equipment, protective systems, and devices referred to in Article 1 (2) do not conform and that they are not for sale until they have been brought into conformity by the manufacturer or his authorized representative established in the Community. During demonstrations, adequate safety measures shall be taken to ensure the protection of persons.

Article 3

Equipment, protective systems, and the devices referred to in Article 1 (2) to which this Directive applies must meet the essential health and safety requirements set out in Annex II which apply to them, account being taken of their intended use.

Article 4

1. Member States shall not prohibit, restrict or impede the placing on the market and putting into service in their territory of equipment, protective systems, or devices referred to in Article 1 (2) which comply with this Directive.

2. Member States shall not prohibit, restrict or impede the placing on the market of components which, accompanied by a certificate of conformity as referred to in Article 8 (3), are intended to be incorporated into equipment or protective systems within the meaning of this Directive.

Article 5

1. Member States shall regard as conforming to all the provisions of this Directive, including the relevant conformity assessment procedures laid down in chapter II:

— equipment, protective systems, and devices referred to in Article 1 (2) accompanied by the EC declaration of conformity referred to in Annex X and bearing the CE marking provided for in Article 10,

— the components referred to in Article 4 (2), accompanied by the certificate of conformity referred to in Article 8 (3).

In the absence of harmonized standards, Member States shall take any steps which they deem necessary to bring to the attention of the parties concerned the existing national technical standards and specifications regarded as important or relevant to the proper implementation of the essential health and safety requirements in Annex II.

2. Where a national standard transposing a harmonized standard, the reference for which has been published in the *Official Journal of the European Communities,* covers one or more of the essential health and safety requirements, the equipment, protective system, device referred to in Article 1 (2), or the component referred to in Article 4 (2), constructed in accordance with that standard shall be presumed to comply with the relevant essential health and safety requirements.

Member States shall publish the references of national standards transposing harmonized standards.

3. Member States shall ensure that appropriate measures are taken to enable the social partners to influence the process of preparing and monitoring the harmonized standards at national level.

Article 6

1. Where a Member State or the Commission considers that the harmonized standards referred to in

Article 5 (2) do not entirely satisfy the relevant essential health and safety requirements referred to in Article 3, the Commission or the Member State concerned shall bring the matter before the Committee set up under Directive 83/189/EEC, hereinafter referred to as 'the Committee', giving reasons therefor. The Committee shall deliver an opinion without delay.

Upon receipt of the Committee's opinion, the Commission shall inform the Member States whether or not it is necessary to withdraw those standards from the published information referred to in Article 5 (2).

2. The Commission may adopt any appropriate measure with a view to ensuring the practical application in a uniform manner of this Directive in accordance with the procedure laid down in paragraph 3.

3. The Commission shall be assisted by a Standing Committee, consisting of representatives appointed by the Member States and chaired by a representative of the Commission.

The Standing Committee shall draw up its own rules of procedure.

The representative of the Commission shall submit to the Committee a draft of the measures to be taken. The Committee shall deliver its opinion on the draft, within a time limit which the chairman may lay down according to the urgency of the matter, if necessary by taking a vote.

The opinion shall be recorded in the minutes; in addition, each Member State shall have the right to ask to have its position recorded in the minutes.

The Commission shall take the utmost account of the opinion delivered by the committee. It shall inform the committee of the manner in which its opinion has been taken into account.

4. The Standing Committee may furthermore examine any question relating to the application of this Directive and raised by its chairman either on the latter's initiative, or at the request of a Member State.

Article 7

1. Whee a Member State ascertains that equipment, protective systems or devices referred to in Article 1 (2) bearing the CE conformity marking and used in accordance with their intended use are liable to endanger the safety of persons and, where appropriate, domestic animals or property, it shall take all appropriate meaures to withdraw such equipment or protective systems from the market, to prohibit the placing on the market, putting into service or use thereof, or to restrict free movement thereof.

The Member State shall immediately inform the Commission of any such measure, indicating the reasons for its decision and, in particular, whether non-conformity is due to:

(a) failure to satisfy the essential requirements referred to in Article 3;

(b) incorrect application of the standards referred to in Article 5 (2);

(c) shortcomings in the standards referred to in Article 5 (2).

2. The Commission shall enter into consultation with the parties concerned without delay. Where the Commission considers, after this consultation, that the measure is justified, it shall immediately so inform the Member State which took the initiative and the other Member States. Where the Commission considers, after this consultation, that the action is unjustified, it shall immediately so inform the Member State which took the initiative and the manufacturer or his authorized representative established within the Community. Where the decision referred to in paragraph 1 is based on a shortcoming in the standards and where the Member State at the origin of the decision maintains its position, the Commission shall immediately inform the Committee in order to initiate the procedures referred to in Article 6 (1).

3. Where equipment or a protective system which does not comply bears the CE conformity marking, the competent Member State shall take appropriate action against the person(s) having affixed the marking and shall so inform the Commission and the other Member States.

4. The Commission shall ensure that the Member States are kept informed of the progress and outcome of this procedure.

CHAPTER II

Conformity assessment procedures

Article 8

1. The procedures for assessing the conformity of equipment, including where necessary the devices referred to in Article 1 (2), shall be as follows:

(a) *equipment-group I and II, equipment-category M 1 and 1*

The manufacturer or his authorized representative established in the Community must, in order to affix the CE marking, follow the CE type-examination procedure (referred to in Annex III), in conjunction with:

— the procedure relating to production quality assurance (referred to in Annex IV),

or

— the procedure relating to product verification (referred to in Annex V);

(b) *Equipment-group I and II, equipment-category M 2 and 2*

(i) In the case of internal combustion engines and electrical equipment in these groups and categories, the manufacturer or his authorized representative established in the Community shall, in order to affix the CE mark, follow the EC-type examination procedure (referred to in Annex III), in conjunction with:

— the procedure relating to conformity to type referred to in Annex VI, or

— the procedure relating to product quality assurance referred to in Annex VII;

(ii) in the case of other equipment in these groups and categories, the manufacturer or his authorized representative established in the Community must, in order to affix the CE mark, follow the procedure relating to internal control of production (referred to in Annex VIII)

and

communicate the dossier provided for in Annex VIII, paragraph 3, to a notified body, which shall acknowledge receipt of it as soon as possible and shall retain it.

(c) *equipment-group II, equipment-category 3*

The manufacturer or his authorized representative established in the Community must, in order to affix the CE marking, follow the procedure relating to internal control of production referred to n Annex VIII;

(d) *equipment-groups I and II*

In addition to the procedures referred to in paragraph 1(a), (b) and (c), the manufacturer or his authorized representative established in the Community may also, in order to affix the CE marking, follow the procedure relating to CE unit verification (referred to in Annex IX).

2. The provisions of 1(a) or 1(d) above shall be used for conformity assessment of autonomous protective systems.

3. The procedures referred to in paragraph 1 shall be applied in respect of components as referred to in Article 4 (2), with the exception of the affixing of the CE marking. A certificate shall be issued by the manufacturer or his authorized representative established in the Community, declaring the conformity of the components with the provisions of this Directive which apply to them and stating their characteristics and how they must be incorporated into equipment or protective systems to assist compliance with the essential requirements applicable to finished equipment or protective systems.

4. In addition, the manufacturer or his authorized representative established in the Community may, in order to affix the CE marking, follow the procedure relating to internal control of production (referred to in Annex VIII) with regard to the safety aspects referred to in point 1.2.7 of Annex II.

5. Notwithstanding the previous paragraphs, the competent authorities may, on a duly justified request, authorize the placing on the market and putting into service on the territory of the Member State concerned of the equipment, protective systems and individual devices referred to in Article 1 (2) in respect of which the procedures referred to in the previous paragraphs have not been applied and the use of which is in the interests of protection.

6. Documents and correspondence relating to the procedures referred to in the abovementioned paragraphs shall be drawn up in one of the official languages of the Member States in which those procedures are being applied or in a language accepted by the notified body.

7. (a) Where the equipment and protective systems are subject to other Community Directives covering other aspects which also provide for the affixing of the CE marking referred to in Article 10, that marking shall indicate that the equipment and protective systems are also presumed to conform with the provisions of those other Directives.

(b) However, where one or more of those Directives allow the manufacturer, during a transitional period, to choose which arrangements to apply, the CE marking shall indicate conformity only with the Directives applied by the manufacturer. In this case, particulars of the said Directives, as published in the *Official Journal of the European Communities*, must be given in the documents, notices or instructions required by the Directives and accompanying the equipment and protective systems.

Article 9

1. Member States shall notify the Commission and the other Member States of the bodies which they have appointed to carry out the procedures referred to in Article 8, together with the specific tasks which these bodies have been appointed to carry out and the identification numbers assigned to them beforehand by the Commission.

The Commission shall publish in the *Official Journal of the European Communities* a list of the notified bodies, with their identification numbers and the tasks for which they have been notified. The Commission shall ensure that this list is kept up to date.

2. Member States shall apply the criteria laid down in Annex XI in assessing the bodies to be indicated in such notification. Bodies meeting the assessment criteria laid down in the relative harmonized standards shall be presumed to fulfil those criteria.

3. A Member State which has approved a body must withdraw its notification if it finds that the body no longer meets the criteria referred to in Annex XI. It shall immediately inform the Commission and the other Member States accordingly.

CHAPTER III

CE conformity marking

Article 10

1. The CE conformity marking shall consist of the initials 'CE'. The form of the marking to be used is shown in Annex X. The CE marking shall be followed by the identification number of the notified body where such body is involved in the production control stage.

2. The CE marking shall be affixed distinctly, visibly, legibly and indelibly to equipment and protective systems, supplementary to the provisions of point 1.0.5. of Annex II.

3. The affixing of markings on the equipment or protective systems which are likely to deceive third parties as to the meaning and form of the CE marking shall be prohibited. Any other marking may be affixed to the equipment or protective systems, provided that the visibility and legibility of the CE marking is not thereby reduced.

Article 11

Without prejudice to Article 7:

(a) where a Member State establishes that the CE marking has been incorrectly affixed, the manufacturer or his authorized representative established within the Community shall be obliged to make the product conform as regards the provisions concerning the CE marking and to end the infringement under the conditions imposed by the Member State;

(b) in the event of continuing non-conformity, the Member State must take all appropriate measures to restrict or prohibit the placing on the market of the product in question or to ensure that it is withdrawn from the market in accordance with the procedures laid down in Article 7.

CHAPTER IV

Final provisions

Article 12

Any decision taken pursuant to this Directive which restricts or prohibits the placing on the market and/or the putting into service or requires the withdrawal from the market of equipment, a protective system, or a device referred to in Article 1 (2) shall state the exact grounds on which it is based. Such a decision shall be notified forthwith to the party concerned, who shall at the same time be informed of the legal remedies available to him under the laws in force in the Member State concerned and of the time limits to which such remedies are subject.

Article 13

Member States shall ensure that all the parties involved in the application of the Directive are bound to observe confidentiality in respect of all information obtained in the performance of carrying out their tasks. This does not affect the obligations of the Member States and of the notified bodies regarding reciprocal information and the dissemination of warnings.

Article 14

1. Directive 76/117/EEC, Directive 79/196/EEC [1] and Directive 82/130/EEC shall be repealed as from 1 July 2003.

2. EC certificates of conformity to the harmonized standards obtained in accordance with the procedures laid down in the Directives referred to in paragraph 1 shall continue to be valid until 30 June 2003 unless they expire before that date. Their validity shall continue to be limited to the harmonized standards indicated in the aforementioned Directives.

3. Member States shall take the necessary action to ensure that the notified bodies which are responsible pursuant to Article 8 (1) to (4) for the assessment of the conformity of electrical equipment placed on the market before 1 July 2003 take account of the results of tests and verifications already carried out under the Directives referred to in paragraph 1.

Article 15

1. Member States shall adopt and publish the laws, regulations and administrative provisions necessary to

[1] OJ No L 43, 20. 2. 1979, p. 20. Directive as last amended by Directive 90/487/EEC (OJ No L 270, 2. 10. 1990, p. 23).

comply with this Directive before 1 September 1995. They shall forthwith inform the Commission thereof.

The Member States shall apply these measures with effect from 1 March 1996.

When Member States adopt the measures referred to in the first subparagraph, they shall contain a reference to this Directive or shall be accompanied by such reference at the time of their official publication. The methods of making such reference shall be laid down by Member States.

2. However, Member States shall allow the placing on the market and the putting into service of equipment and protective systems conforming with the national regulations in force in their territory at the date of adoption of this Directive for the period until 30 June 2003.

Article 16

This Directive is addressed to the Member States.

Done at Brussels, 23 March 1994.

For the European Parliament	*For the Council*
The President	*The President*
E. KLEPSCH	TH. PANGALOS

ANNEX I

CRITERIA DETERMINING THE CLASSIFICATION OF EQUIPMENT-GROUPS INTO CATEGORIES

1. **Equipment-group I**

(a) Category M 1 comprises equipment designed and, where necessary, equipped with additional special means of protection to be capable of functioning in conformity with the operational parameters established by the manufacturer and ensuring a very high level of protection.

Equipment in this category is intended for use in underground parts of mines as well as those parts of surface installations of such mines endangered by firedamp and/or combustible dust.

Equipment in this category is required to remain functional, even in the event of rare incidents relating to equipment, with an explosive atmosphere present, and is characterized by means of protection such that:

— either, in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection,

— or the requisite level of protection is assured in the event of two faults occurring independently of each other.

Equipment in this category must comply with the supplementary requirements referred to in Annex II, 2.0.1.

(b) Category M 2 comprises equipment designed to be capable of functioning in conformity with the operational parameters established by the manufacturer and ensuring a high level of protection.

Equipment in this category is intended for use in underground parts of mines as well as those parts of surface installations of such mines likely to be endangered by firedamp and/or combustible dust.

This equipment is intended to be de-energized in the event of an explosive atmosphere.

The means of protection relating to equipment in this category assure the requisite level of protection during normal operation and also in the case of more severe operating conditions, in particular those arising from rough handling and changing environmental conditions.

Equipment in this category must comply with the supplementary requirements referred to in Annex II, 2.0.2.

2. **Equipment-group II**

(a) Category 1 comprises equipment designed to be capable of functioning in conformity with the operational parameters established by the manufacturer and ensuring a very high level of protection.

Equipment in this category is intended for use in areas in which explosive atmospheres caused by mixtures of air and gases, vapours or mists or by air/dust mixtures are present continuously, for long periods or frequently.

Equipment in this category must ensure the requisite level of protection, even in the event of rare incidents relating to equipment, and is characterized by means of protection such that:

— either, in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection,

— or the requisite level of protection is assured in the event of two faults occurring independently of each other.

Equipment in this category must comply with the supplementary requirements referred to in Annex II, 2.1.

(b) Category 2 comprises equipment designed to be capable of functioning in conformity with the operational parameters established by the manufacturer and of ensuring a high level of protection.

Equipment in this category is intended for use in areas in which explosive atmospheres caused by gases, vapours, mists or air/dust mixtures are likely to occur.

The means of protection relating to equipment in this category ensure the requisite level of protection, even in the event of frequently occurring disturbances or equipment faults which normally have to be taken into account.

Equipment in this category must comply with the supplementary requirements referred to in Annex II, 2.2.

(c) Category 3 comprises equipment designed to be capable of functioning in conformity with the operating parameters established by the manufacturer and ensuring a normal level of protection.

Equipment in this category is intended for use in areas in which explosive atmospheres caused by gases, vapours, mists, or air/dust mixtures are unlikely to occur or, if they do occur, are likely to do so only infrequently and for a short period only.

Equipment in this category ensures the requisite level of protection during normal operation.

Equipment in this category must comply with the supplementary requirements referred to in Annex II, 2.3.

ANNEX II

ESSENTIAL HEALTH AND SAFETY REQUIREMENTS RELATING TO THE DESIGN AND CONSTRUCTION OF EQUIPMENT AND PROTECTIVE SYSTEMS INTENDED FOR USE IN POTENTIALLY EXPLOSIVE ATMOSPHERES

Preliminary observations

A. Technological knowledge, which can change rapidly, must be taken into account as far as possible and be utilized immediately.

B. For the devices referred to in Article 1 (2), the essential requirements shall apply only in so far as they are necessary for the safe and reliable functioning and operation of those devices with respect to the risks of explosion.

1. COMMON REQUIREMENTS FOR EQUIPMENT AND PROTECTIVE SYSTEMS

1.0. **General requirements**

1.0.1. *Principles of integrated explosion safety*

Equipment and protective systems intended for use in potentially explosive atmospheres must be designed from the point of view of integrated explosion safety.

In this connection, the manufacturer must take measures:

— above all, if possible, to prevent the formation of explosive atmospheres which may be produced or released by equipment and by protective systems themselves,

— to prevent the ignition of explosive atmospheres, taking into account the nature of every electrical and non-electrical source of ignition,

— should an explosion nevertheless occur which could directly or indirectly endanger persons and, as the case may be, domestic animals or property, to halt it immediately and/or to limit the range of explosion flames and explosion pressures to a sufficient level of safety.

1.0.2. Equipment and protective systems must be designed and manufactured after due analysis of possible operating faults in order as far as possible to preclude dangerous situations.

Any misuse which can reasonably be anticipated must be taken into account.

1.0.3. *Special checking and maintenance conditions*

Equipment and protective systems subject to special checking and maintenance conditions must be designed and constructed with such conditions in mind.

1.0.4. *Surrounding area conditions*

Equipment and protective systems must be so designed and constructed as to be capable of coping with actual or foreseeable surrounding area conditions.

1.0.5. *Marking*

All equipment and protective systems must be marked legibly and indelibly with the following minimum particulars;

— name and address of the manufacturer,

— CE marking (see Annex X, point A),

— designation of series or type,

— serial number, if any,

— year of construction,

— the specific marking of explosion protection ⟨Ex⟩ followed by the symbol of the equipment group and category,

— for equipment-group II, the letter 'G' (concerning explosive atmospheres caused by gases, vapours or mists),

and/or

the letter 'D' (concerning explosive atmospheres caused by dust).

Furthermore, where necessary, they must also be marked with all information essential to their safe use.

1.0.6. *Instructions*

(a) All equipment and protective systems must be accompanied by instructions, including at least the following particulars:

— a recapitulation of the information with which the equipment or protective system is marked, except for the serial number (see 1.0.5.), together with any appropriate additional information to facilitate maintenance (e.g. address of the importer, repairer, etc.);

— instructions for safe:

— putting into service,

— use,

— assembling and dismantling,

— maintenance (servicing and emergency repair),

— installation,

— adjustment;

— where necessary, an indication of the danger areas in front of pressure-relief devices;

— where necessary, training instructions;

— details which allow a decision to be taken beyond any doubt as to whether an item of equipment in a specific category or a protective system can be used safely in the intended area under the expected operating conditions;

— electrical and pressure parameters, maximum surface temperatures and other limit values;

— where necessary, special conditions of use, including particulars of possible misuse which experience has shown might occur;

— where necessary, the essential chracteristics of tools which may be fitted to the equipment or protective system.

(b) The instructions must be drawn up in one of the Community languages by the manufacturer or his authorized representative established in the Community.

On being put into service, all equipment and protective systems must be accompanied by a translation of the instructions in the language or languages of the country in which the equipment or protective system is to be used and by the instructions in the original language.

This translation must be made by either the manufacturer or his authorized representative established in the Community or the person introducing the equipment or protective system into the language area in question.

By way of derogation from this requirement, the maintenance instructions for use by the specialist personnel employed by the manufacturer or his authorized representative established in the Community may be drawn up in a single Community language understood by that personnel.

(c) The instructions must contain the drawings and diagrams necessary for the putting into service, maintenance, inspection, checking of correct operation and, where appropriate, repair of the equipment or protective system, together with all useful instructions, in particular with regard to safety.

(d) Literature describing the equipment or protective system must not contradict the instructions with regard to safety aspects.

1.1. **Selection of materials**

1.1.1. The materials used for the construction of equipment and protective systems must not trigger off an explosion, taking into account foreseeable operational stresses.

1.1.2. Within the limits of the operating conditions laid down by the manufacturer, it must not be possible for a reaction to take place between the materials used and the constituents of the potentially explosive atmosphere which could impair explosion protection.

1.1.3. Materials must be so selected that predictable changes in their characteristics and their compatibility in combination with other materials will not lead to a reduction in the protection afforded; in particular, due account must be taken of the material's corrosion and wear resistance, electrical conductivity, impact strength, ageing resistance and the effects of temperature variations.

1.2. **Design and Construction**

1.2.1. Equipment and protective systems must be designed and constructed with due regard to technological knowledge of explosion protection so that they can be safely operated throughout their foreseeable lifetime.

1.2.2. Components to be incorporated into or used as replacements in equipment and protective systems must be so designed and constructed that they function safely for their intended purpose of explosion protection when they are installed in accordance with the manufacturer's instructions.

1.2.3. *Enclosed structures and prevention of leaks*

Equipment which may release flammable gases or dusts must wherever possible employ enclosed structures only.

If equipment contains openings or non-tight joints, these must as far as possible be designed in such a way that developing gases or dusts cannot give rise to explosive atmospheres outside the equipment.

Points where materials are introduced or drawn off must, as far as possible, be designed and equipped so as to limit escapes of flammable materials during filling or draining.

1.2.4. *Dust deposits*

Equipment and protective systems which are intended to be used in areas exposed to dust must be so designed that deposit dust on their surfaces is not ignited.

In general, dust deposits must be limited where possible. Equipment and protective systems must be easily cleanable.

The surface temperatures of equipment parts must be kept well below the glow temperature of the deposit dust.

The thickness of deposit dust must be taken into consideration and, if appropriate, means must be taken to limit the temperature in order to prevent a heat build up.

1.2.5. *Additional means of protection*

Equipment and protective systems which may be exposed to certain types of external stresses must be equipped, where necessary, with additional means of protection.

Equipment must withstand relevant stresses, without adverse effect on explosion protection.

1.2.6. *Safe opening*

If equipment and protective systems are in a housing or a locked container forming part of the explosion protection itself, it must be possible to open such housing or container only with a special tool or by means of appropriate protection measures.

1.2.7. Protection against other hazards

Equipment and protective systems must be so designed and manufactured as to:

(a) avoid physical injury or other harm which might be caused by direct or indirect contact;

(b) assure that surface temperatures of accessible parts or radiation which would cause a danger, are not produced;

(c) eliminate non-electrical dangers which are revealed by experience;

(d) assure that foreseeable conditions of overload shall not give rise to dangerous situations.

Where, for equipment and protective systems, the risks referred to in this paragraph are wholly or partly covered by other Community Directives, this Directive shall not apply or shall cease to apply in the case of such equipment and protective systems and of such risks upon application of those specific Directives.

1.2.8. *Overloading of equipment*

Dangerous overloading of equipment must be prevented at the design stage by means of integrated measurement, regulation and control devices, such as over-current cut-off switches, temperature limiters, differential pressure switches, flowmeters, time-lag relays, overspeed monitors and/or similar types of monitoring devices.

1.2.9. *Flameproof enclosure systems*

If parts which can ignite an explosive atmosphere are placed in an enclosure, measures must be taken to ensure that the enclosure withstands the pressure developed during an internal explosion of an explosive mixture and prevents the transmission of the explosion to the explosive atmosphere surrounding the enclosure.

1.3. **Potential ignition sources**

1.3.1. *Hazards arising from different ignition sources*

Potential ignition sources such as sparks, flames, electric arcs, high surface temperatures, acoustic energy, optical radiation, electromagnetic waves and other ignition sources must not occur.

1.3.2. *Hazards arising from static electricity*

Electrostatic charges capable of resulting in dangerous discharges must be prevented by means of appropriate measures.

1.3.3. *Hazards arising from stray electric and leakage currents*

Stray electric and leakage currents in conductive equipment parts which could result in, for example, the occurrence of dangerous corrosion, overheating of surfaces or sparks capable of provoking an ignition must be prevented.

1.3.4. *Hazards arising from overheating*

Overheating caused by friction or impacts occurring, for example, between materials and parts in contact with each other while rotating or through the intrusion of foreign bodies must, as far as possible, be prevented at the design stage.

1.3.5. *Hazards arising from pressure compensation operations*

Equipment and protective systems must be so designed or fitted with integrated measuring, control and regulation devices that pressure compensations arising from them do not generate shock waves or compressions which may cause ignition.

1.4. **Hazards arising from external effects**

1.4.1. Equipment and protective systems must be so designed and constructed as to be capable of performing their intended function in full safety, even in changing environmental conditions and in the presence of extraneous voltages, humidity, vibrations, contamination and other external effects, taking into account the limits of the operating conditions established by the manufacturer.

1.4.2. Equipment parts used must be appropriate to the intended mechanical and thermal stresses and capable of withstanding attack by existing or foreseeable aggressive substances.

1.5. **Requirements in respect of safety-related devices**

1.5.1. Safety devices must function independently of any measurement or control devices required for operation.

As far as possible, failure of a safety device must be detected sufficiently rapidly by appropriate technical means to ensure that there is only very little likelihood that dangerous situations will occur.

For electrical circuits the fail-safe principle is to be applied in general.

Safety-related switching must in general directly actuate the relevant control devices without intermediate software command.

1.5.2. In the event of a safety device failure, equipment and/or protective systems shall, wherever possible, be secured.

1.5.3. Emergency stop controls of safety devices must, as far as possible, be fitted with restart lockouts. A new start command may take effect on normal operation only after the restart lockouts have been intentionally reset.

1.5.4. *Control and display units*

Where control and display units are used, they must be designed in accordance with ergonomic principles in order to achieve the highest possible level of operating safety with regard to the risk of explosion.

1.5.5. *Requirements in respect of devices with a measuring function for explosion protection.*

In so far as they relate to equipment used in explosive atmospheres, devices with a measuring function must be designed and constructed so that they can cope with foreseeable operating requirements and special conditions of use.

1.5.6. Where necessary, it must be possible to check the reading accuracy and serviceability of devices with a measuring function.

1.5.7. The design of devices with a measuring function must incorporate a safety factor which ensures that the alarm threshold lies far enough outside the explosion and/or ignition limits of the atmospheres to be registered, taking into account, in particular, the operating conditions of the installation and possible aberrations in the measuring system.

1.5.8. *Risks arising from software*

In the design of software-controlled equipment, protective systems and safety devices, special account must be taken of the risks arising from faults in the programme.

1.6. **Integration of safety requirements relating to the system**

1.6.1. Manual override must be possible in order to shut down the equipment and protective systems incorporated within automatic processes which deviate from the intended operating conditions, provided that this does not compromise safety.

1.6.2. When the emergency shutdown system is actuated, accumulated energy must be dispersed as quickly and as safely as possible or isolated so that it no longer constitutes a hazard.

This does not apply to electrochemically-stored energy.

1.6.3. *Hazards arising from power failure*

Where equipment and protective systems can give rise to a spread of additional risks in the event of a power failure, it must be possible to maintain them in a safe state of operation independently of the rest of the installation.

1.6.4. *Hazards arising from connections*

Equipment and protective systems must be fitted with suitable cable and conduit entries.

When equipment and protective systems are intended for use in combination with other equipment and protective systems, the interface must be safe.

1.6.5. *Placing of warning devices as parts of equipment*

Where equipment or protective systems are fitted with detection or alarm devices for monitoring the occurrence of explosive atmospheres, the necessary instructions must be provided to enable them to be provided at the appropriate places.

2. SUPPLEMENTARY REQUIREMENTS IN RESPECT OF EQUIPMENT

2.0. **Requirements applicable to equipment in category M of equipment-group I**

2.0.1. *Requirements applicable to equipment in category M 1 of equipment-group I*

2.0.1.1. Equipment must be so designed and constructed that sources of ignition do not become active, even in the event of rare incidents relating to equipment.

Equipment must be equipped with means of protection such that:

— either, in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection,

— or, the requisite level of protection is ensured in the event of two faults occurring independently of each other.

Where necessary, this equipment must be equipped with additional special means of protection.

It must remain functional with an explosive atmosphere present.

2.0.1.2. Where necessary, equipment must be so constructed that no dust can penetrate it.

2.0.1.3. The surface temperatures of equipment parts must be kept clearly below the ignition temperature of the foreseeable air/dust mixtures in order to prevent the ignition of suspended dust.

2.0.1.4. Equipment must be so designed that the opening of equipment parts which may be sources of ignition is possible only under non-active or intrinsically safe conditions. Where it is not possible to render equipment non-active, the manufacturer must affix a warning label to the opening part of the equipment.

If necessary, equipment must be fitted with appropriate additional interlocking systems.

2.0.2. *Requirements applicable to equipment in category M 2 of equipment-group I*

2.0.2.1. Equipment must be equipped with means of protection ensuring that sources of ignition do not become active during normal operation, even under more severe operating conditions, in particular those arising from rough handling and changing environmental conditions.

The equipment is intended to be de-energized in the event of an explosive atmosphere.

2.0.2.2. Equipment must be so designed that the opening of equipment parts which may be sources of ignition is possible only under non-active conditions or via appropriate interlocking systems. Where it is not possible to render equipment non-active, the manufacturer must affix a warning label to the opening part of the equipment.

2.0.2.3. The requirements regarding explosion hazards arising from dust applicable to category M 1 must be applied.

2.1. **Requirements applicable to equipment in category 1 of equipment-group II**

2.1.1. *Explosive atmospheres caused by gases, vapours or hazes*

2.1.1.1. Equipment must be so designed and constructed that sources of ignition do not become active, even in event of rare incidents relating to equipment.

It must be equipped with means of protection such that:

— either, in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection,

— or, the requisite level of protection is ensured in the event of two faults occurring independently of each other.

2.1.1.2. For equipment with surfaces which may heat up, measures must be taken to ensure that the stated maximum surface temperatures are not exceeded even in the most unfavourable circumstances.

Temperature rises caused by heat build-ups and chemical reactions must also be taken into account.

2.1.1.3. Equipment must be so designed that the opening of equipment parts which might be sources of ignition is possible only under non-active or intrinsically safe conditions. Where it is not possible to render equipment non-active, the manufacturer must affix a warning label to the opening part of the equipment.

If necessary, equipment must be fitted with appropriate additional interlocking systems.

2.1.2. *Explosive atmospheres caused by air/dust mixtures*

2.1.2.1. Equipment must be so designed and constructed that ignition of air/dust mixtures does not occur even in the event of rare incidents relating to equipment.

It must be equipped with means of protection such that

— either, in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection,

— or, the requisite level of protection is ensured in the event of two faults occurring independently of each other.

2.1.2.2. Where necessary, equipment must be so designed that dust can enter or escape from the equipment only at specifically designated points.

This requirement must also be met by cable entries and connecting pieces.

2.1.2.3. The surface temperatures of equipment parts must be kept well below the ignition temperature of the foreseeable air/dust mixtures in order to prevent the ignition of suspended dust.

2.1.2.4. With regard to the safe opening of equipment parts, requirement 2.1.1.3 applies.

2.2. **Requirements for category 2 of equipment-group II**

2.2.1. *Explosive atmospheres caused by gases, vapours or mists*

2.2.1.1. Equipment must be so designed and constructed as to prevent ignition sources arising, even in the event of frequently occurring disturbances or equipment operating faults, which normally have to be taken into account.

2.2.1.2. Equipment parts must be so designed and constructed that their stated surface temperatures are not exceeded, even in the case of risks arising from abnormal situations anticipated by the manufacturer.

2.2.1.3. Equipment must be so designed that the opening of equipment parts which might be sources of ignition is possible only under non-active conditions or via appropriate interlocking systems. Where it is not possible to render equipment non-active, the manufacturer must affix a warning label to the opening part of the equipment.

2.2.2. *Explosive atmospheres caused by air/dust mixtures*

2.2.2.1. Equipment must be designed and constructed so that ignition of air/dust mixtures is prevented, even in the event of frequently occurring disturbances or equipment operating faults which normally have to be taken into account.

2.2.2.2. With regard to surface temperatures, requirement 2.1.2.3 applies.

2.2.2.3. With regard to protection against dust, requirement 2.1.2.2 applies.

2.2.2.4. With regard to the safe opening of equipment parts, requirement 2.2.1.3 applies.

2.3. **Requirements applicable to equipment in category 3 of equipment-group II**

2.3.1. *Explosive atmospheres caused by gases, vapours or mists*

2.3.1.1. Equipment must be so designed and constructed as to prevent foreseeable ignition sources which can occur during normal operation.

2.3.1.2. Surface temperatures must not exceed the stated maximum surface temperatures under intended operating conditions. Higher temperatures in exceptional circumstances may be allowed only if the manufacturer adopts special additional protective measures.

2.3.2. *Explosive atmospheres caused by air/dust mixtures*

2.3.2.1. Equipment must be so designed and constructed that air/dust mixtures cannot be ignited by foreseeable ignition sources likely to exist during normal operation.

2.3.2.2. With regard to surface temperatures, requirement 2.1.2.3 applies.

2.3.2.3. Equipment, including cable entries and connecting pieces, must be so constructed that, taking into account the size of its particles, dust can neither develop explosive mixtures with air nor form dangerous accumulations inside the equipment.

3. SUPPLEMENTARY REQUIREMENTS IN RESPECT OF PROTECTIVE SYSTEMS

3.0. **General requirements**

3.0.1. Protective systems must be dimensioned in such a way as to reduce the effects of an explosion to a sufficient level of safety.

3.0.2. Protective systems must be designed and capable of being positional in such a way that explosions are prevented from spreading through dangerous chain reactions or flashover and incipient explosions do not become detonations.

3.0.3. In the event of a power failure, protective systems must retain their capacity to function for a period sufficient to avoid a dangerous situation.

3.0.4. Protective systems must not fail due to outside interference.

3.1. **Planning and design**

3.1.1. *Characteristics of materials*

With regard to the characteristics of materials, the maximum pressure and temperature to be taken into consideration at the planning stage are the expected pressure during an explosion occurring under extreme operating conditions and the anticipated heating effect of the flame.

3.1.2. Protective systems designed to resist or contain explosions must be capable of withstanding the shock wave produced without losing system integrity.

3.1.3. Accessories connected to protective systems must be capable of withstanding the expected maximum explosion pressure without losing their capacity to function.

3.1.4. The reactions caused by pressure in peripheral equipment and connected pipe-work must be taken into consideration in the planning and design of protective systems.

3.1.5. *Pressure-relief systems*

If it is likely that stresses on protective systems will exceed their structural strength, provision must be made in the design for suitable pressure-relief devices which do not endanger persons in the vicinity.

3.1.6. *Explosion suppression systems*

Explosion suppression systems must be so planned and designed that they react to an incipient explosion at the earliest possible stage in the event of an incident and counteract it to best effect, which due regard to the maximum rate of pressure increase and the maximum explosion pressure.

3.1.7. *Explosion decoupling systems*

Decoupling systems intended to disconnect specific equipment as swiftly as possible in the event of incipient explosions by means of appropriate devices must be planned and designed so as to remain proof against the transmission of internal ignition and to retain their mechanical strength under operating conditions.

3.1.8. Protective systems must be capable of being integrated into a circuit with a suitable alarm threshold so that, if necessary, there is cessation of product feed and output and shutdown of equipment parts which can no longer function safely.

ANNEX III

MODULE EC-TYPE EXAMINATION

1. This module describes that part of the procedure by which a notified body ascertains and attests that a specimen representative of the production envisaged meets the relevant applicable provisions of the Directive.

2. The application for the EC-type examination shall be lodged by the manufacturer or his authorized representative established within the Community with a notified body of his choice.

The application shall include:

- the name and address of the manufacturer and, if the application is lodged by the authorized representative, his name and address in addition;
- a written declaration that the same application has not been lodged with any other notified body;
- the technical documentation, as described in point 3.

The applicant shall place at the disposal of the notified body a specimen representative of the production envisaged and hereinafter called 'type'. The notified body may request further specimens if needed for carrying out the test programme.

3. The technical documentation shall enable the conformity of the product with the requirements of the Directive to be assessed. It shall, to the extent necessary for such assessment, cover the design, manufacture and operation of the product and shall to that extent contain:

- a general type-description;
- design and manufacturing drawings and layouts of components, sub-assemblies, circuits, etc.;
- descriptions and explanations necessary for the understanding of said drawings and layouts and the operation of the product;
- a list of the standards referred to in Article 5, applied in full or in part, and descriptions of the solutions adopted to meet the essential requirements of the Directive where the standards referred to in Article 5 have not been applied;
- results of design calculations made, examinations carried out, etc.;
- test reports.

4. The notified body shall:

4.1. examine the technical documentation, verify that the type has been manufactured in conformity with the technical documentation and identify the elements which have been designed in accordance with the relevant provisions of the standards referred to in Article 5, as well as the components which have been designed without applying the relevant provisions of those standards;

4.2. perform or have performed the appropriate examinations and necessary tests to check whether the solutions adopted by the manufacturer meet the essential requirements of the Directive where the standards referred to in Article 5 have not ben applied;

4.3. perform or have performed the appropriate examinations and necessary tests to check whether these have actually been applied, where the manufacturer has chosen to apply the relevant standards;

4.4. agree with the applicant the location where the examinations and necessary tests shall be carried out.

5. Where the type meets the provisions of the Directive, the notified body shall issue an EC-type-examination certificate to the applicant. The certificate shall contain the name and address of the manufacturer, conclusions of the examination and the necessary data for identification of the approved type.

A list of the relevant parts of the technical documentation shall be annexed to the certificate and a copy kept by the notified body.

If the manufacturer or his authorized representative established in the Community is denied a type certification, the notified body shall provide detailed reasons for such denial.

Provision shall be made for an appeals procedure.

6. The applicant shall inform the notified body which holds the technical documentation concerning the EC-type-examination certificate of all modifications to the approved equipment or protective system which must receive further approval where such changes may effect conformity with the essential requirements or with the prescribed conditions for use of the product. This further approval is given in the form of an addition to the original EC-type-examination certificate.

7. Each notified body shall communicate to the other notified bodies the relevant information concerning the EC-type-examination certificates and additions issued and withdrawn.

8. The other notified bodies may receive copies of the EC-type-examination certificates and/or their additions. The annexes to the certificates shall be kept at the disposal of the other notified bodies.

9. The manufacturer or his authorized representative established in the Community shall keep with the technical documentation copies of EC-type-examination certificates and their additions for a period ending at least 10 years after the last equipment or protective system was manufactured.

Where neither the manufacturer nor his authorized representative is established within the Community, the obligation to keep the technical documentation available shall be the responsibility of the person who places the product on the Community market.

ANNEX IV

MODULE: PRODUCTION QUALITY ASSURANCE

1. This module describes the procedure whereby the manufacturer who satisfies the obligations of point 2 ensures and declares that the products concerned are in conformity with the type as described in the EC-type-examination certificate and satisfy the requirements of the Directive which apply to them. The manufacturer, or his authorized representative established in the Community, shall affix the CE marking to each piece of equipment and draw up a written declaration of conformity. The CE marking shall be accompanied by the identification number of the notified body responsible for EC monitoring, as specified in Section 4.

2. The manufacturer shall operate an approved quality system for production, final equipment inspection and testing as specified in Section 3 and shall be subject to monitoring as specified in Section 4.

3. **Quality system**

3.1. The manufacturer shall lodge an application for assessment of his quality system with a notified body of his choice, for the equipment concerned.

The application shall include:

— all relevant information for the product category envisaged;

— the documentation concerning the quality system;

— technical documentation on the approved type and a copy of the EC-type-examination certificate.

3.2. The quality system shall ensure compliance of the equipment with the type as described in the EC-type-examination certificate and with the requirements of the Directive which apply to them.

All the elements, requirements and provisions adopted by the manufacturer shall be documented in a systematic and orderly manner in the form of written policies, procedures and instructions. The quality system documentation must permit a consistent interpretation of quality programmes, plans, manuals and records.

It shall contain, in particular, an adequate description of

— the quality objectives and the organizational structure, responsibilities and powers of the management with regard to equipment quality;

— the manufacturing, quality control and quality assurance techniques, processes and systematic actions which will be used;

— the examinations and tests which will be carried out before, during and after manufacture and the frequency with which they will be carried out;

— the quality records, such as inspection reports and test data, calibration data, reports on the qualifications of the personnel concerned, etc.;

— the means to monitor the achievement of the required equipment quality and the effective operation of the quality system.

3.3. The notified body shall assess the quality system to determine whether it satisfies the requirements referred to in Section 3.2. It shall presume conformity with these requirements in respect of quality systems which implement the relevant harmonized standard. The auditing team shall have at least one member with experience of evaluation in the equipment technology concerned. The evaluation procedure shall include an inspection visit to the manufacturer's premises. The decision shall be notified to the manufacturer. The notification shall contain the conclusions of the examination and the reasoned assessment decision.

3.4. The manufacturer shall undertake to fulfil the obligations arising out of the quality system as approved and to uphold the system so that it remains adequate and efficient.

The manufacturer or his authorized representative shall inform the notified body which has approved the quality system of any intended updating of the quality system.

The notified body shall evaluate the modifications proposed and decide whether the amended quality system will still satisfy the requirements referred to in Section 3.2 or whether a re-assessment is required.

It shall notify its decision to the manufacturer. The notification shall contain the conclusions of the examination and the reasoned assessment decision.

4. **Surveillance under the responsibility of the notified body**

4.1. The purpose of surveillance is to make sure that the manufacturer duly fulfils the obligations arising out of the approved quality system.

4.2. The manufacturer shall, for inspection purposes, allow the notified body access to the manufacture, inspection, testing and storage premises and shall provide it with all necessary information, in particular

— the quality system documentation

— the quality records, such as inspection reports and text data, calibration data, reports on the qualifications of the personnel concerned, etc.

4.3. The notified body shall periodically carry out audits to ensure that the manufacturer maintains and applies the quality system and shall provide an audit report to the manufacturer.

4.4. Furthermore, the notified body may pay unexpected visits to the manufacturer. During such visits, the notified body may carry out tests, or arrange for tests to be carried out, to check that the quality system is functioning correctly, if necessary. The notified body shall provide the manufacturer with a visit report and, if a test has taken place, with a test report.

5. The manufacturer shall, for a period ending at least 10 years after the last piece of equipment was manufactured, keep at the disposal of the national authorities:

— the documentation referred to in the second indent of Section 3.1;

— the updating referred to in the second paragraph of Section 3.4;

— the decisions and reports from the notified body which are referred to in Section 3.4, last paragraph, Section 4.3 and Secton 4.4.

6. Each notified body shall apprise the other notified bodies of the relevant information concerning the quality system approvals issued and withdrawn.

ANNEX V

MODULE: PRODUCT VERIFICATION

1. This module describes the procedure whereby a manufacturer or his authorized representative established within the Community checks and attests that the equipment subject to the provisions of point 3 are in conformity with the type as described in the EC-type-examination certificate and satisfy the relevant requirements of the Directive.

2. The manufacturer shall take all measures necessary to ensure that the manufacturing process guarantees conformity of the equipment with the type as described in the EC-type-examination certificate and with the requirements of the Directive which apply to them. The manufacturer or his authorized representative established in the Community shall affix the CE marking to each piece of equipment and shall draw up a declaration of conformity.

3. The notified body shall carry out the appropriate examinations and tests in order to check the conformity of the equipment, protective system or device referred to in Article 1 (2), with the relevant requirements of the Directive, by examining and testing every product as specified in Section 4.

   The manufacturer or his authorized representative shall keep a copy of the declaration of conformity for a period ending at least 10 years after the last piece of equipment was manufactured.

4. **Verification by examination and testing of each piece of equipment.**

4.1. All equipment shall be individually examined and appropriate tests as set out in the relevant standard(s) referred to in Article 5 or equipment tests shall be carried out in order to verify their conformity with the type as described in the EC-type-examination certificate and the relevant requirements of the Directive.

4.2. The notified body shall affix or have affixed its identification number to each approved item of equipment and shall draw up a written certificate of conformity relating to the tests carried out.

4.3. The manufacturer or his authorized representative shall ensure that he is able to supply the notified body's certificates of conformity on request.

ANNEX VI

MODULE: CONFORMITY TO TYPE

1. This module describes that part of the procedure whereby the manufacturer or his authorized representative established within the Community ensures and declares that the equipment in question is in conformity with the type as described in the EC-type-examination certificate and satisfy the requirements of the Directive applicable to them. The manufacturer or his authorized representative established within the Community shall affix the CE marking to each piece of equipment and draw up a written declaration of conformity.

2. The manufacturer shall take all measures necessary to ensure that the manufacturing process assures compliance of the manufactured equipment or protective systems with the type as described in the EC-type-examination certificate and with the relevant requirements of the Directive.

3. The manufacturer or his authorized representative shall keep a copy of the declaration of conformity for a period ending at least 10 years after the last piece of equipment was manufactured. Where neither the manufacturer nor his authorized representative is established within the Community, the obligation to keep the technical documentation available shall be the responsibility of the person who places the equipment or protective system on the Community market.

   For each piece of equipment manufactured, tests relating to the anti-explosive protection aspects of the product shall be carried out by the manufacturer or on his behalf. The tests shall be carried out under the responsibility of a notified body, chosen by the manufacturer.

   On the responsibility of the notified body, the manufacturer shall affix the former's identification number during the manufacturing process.

ANNEX VII

MODULE: PRODUCT QUALITY ASSURANCE

1. This module describes the procedure whereby the manufacturer who satisfies the obligations of Section 2 ensures and declares that the equipment is in conformity with the type as described in the EC-type-examination certificate. The manufacturer or his authorized representative established within the Community shall affix the CE marking to each product and draw up a written declaration of conformity. The CE marking shall be accompanied by the identification number of the notified body responsible for surveillance as specified in Section 4.

2. The manufacturer shall operate an approved quality system for the final inspection and testing of equipment as specified in Section 3 below and shall be subject to surveillance as specified in Section 4 below.

3. **Quality system**

3.1. The manufacturer shall lodge an application for assessment of his quality system for the equipment and protective systems, with a notified body of his choice.

The application shall include:

— all relevant information for the product category envisaged;

— documentation on the quality system;

— technical documentation on the approved type and a copy of the EC-type-examination certificate.

3.2. Under the quality system, each piece of equipment shall be examined and appropriate tests as set out in the relevant standard(s) referred to in Article 5 or equivalent tests shall be carried out in order to ensure its conformity with the relevant requirements of the Directive. All the elements, requirements and provisions adopted by the manufacturer shall be documented in a systematic and orderly manner in the form of written policies, procedures and instruments. This quality system documentation must permit a consistent interpretation of the quality programmes, plans, manuals and records.

It shall contain, in particular, an adequate description of:

— the quality objectives and the organizational structure, responsibilities and powers of the management with regard to product quality;

— the examinations and tests which will be carried out after manufacture;

— the means to monitor the effective operation of the quality system;

— quality records, such as inspection reports and test data, calibration data, reports on the qualifications of the personnel concerned, etc.

3.3. The notified body shall assess the quality system to determine whether it satisfies the requirements referred to in Section 3.2. It shall presume conformity with these requirements in respect of quality systems which implement the relevant harmonized standard.

The auditing team shall have at least one member experienced as an assessor in the product technology concerned. The assessment procedure shall include an assessment visit to the manufacturer's premises.

The decision shall be notified to the manufacturer. The notification shall contain the conclusions of the examination and the reasoned assessment decision.

3.4. The manufacturer shall undertake to discharge the obligations arising from the quality system as approved and to maintain it in an appropriate and efficient manner.

The manufacturer or his authorized representative shall inform the notified body which has approved the quality system of any intended updating of the quality system.

The notified body shall evaluate the modifications proposed and decide whether the modified quality system will still satisfy the requirements referred to in Section 3.2 or whether a re-assessment is required.

It shall notify its decision to the manufacturer. The notification shall contain the conclusions of the examination and the reasoned assessment decision.

4. **Surveillance under the responsibility of the notified body**

4.1. The purpose of surveillance is to ensure that the manufacturer duly fulfils the obligations arising out of the approved quality system.

4.2. The manufacturer shall for inspection purposes allow the notified body access to the inspection, testing and storage premises and shall provide it with all necessary information, in particular:

— quality system documentation;

— technical documentation;

— quality records, such as inspection reports and test data, calibration data, reports on the qualifications of the personnel concerned, etc.

4.3. The notified body shall periodically carry out audits to ensure that the manufacturer maintains and applies the quality system and shall provide an audit report to the manufacturer.

4.4. Furthermore, the notified body may pay unexpected visits to the manufacturer. At the time of such visits, the notified body may carry out tests or arrange for tests to be carried out in order to check the proper functioning of the quality system, where necessary; it shall provide the manufacturer with a visit report and, if a test has been carried out, with a test report.

5. The manufacturer shall, for a period ending at least 10 years after the last piece of equipment was manufactured, keep at the disposal of the national authorities:

— the documentation referred to in the third indent of Section 3.1;

— the updating referred to in the second paragraph of Section 3.4;

— the decisions and reports from the notified body which are referred to in Section 3.4, last paragraph, Section 4.3 and Section 4.4.

6. Each notified body shall forward to the other notified bodies the relevant information concerning the quality system approvals issued and withdrawn.

ANNEX VIII

MODUL: INTERNAL CONTROL OF PRODUCTION

1. This module describes the procedure whereby the manufacturer or his authorized representative established within the Community, who carries out the obligations laid down in Section 2, ensures and declares that the equipment satisfy the requirements of the Directive applicable to it. The manufacturer or his authorized representative established within the Community shall affix the CE marking to each piece of equipment and draw up a written declaration of conformity.

2. The manufacturer shall establish the technical documentation described in Section 3 and he or his authorized representative established within the Community shall keep it at the disposal of the relevant national authorities for inspection purposes for a period ending at least 10 years after the last piece of equipment was manufactured.

   Where neither the manufacturer nor his authorized representative is established within the Community, the obligation to keep the technical documentation available shall be the responsibility of the person who places the equipment on the Community market.

3. Technical documentation shall enable the conformity of the equipment with the relevant requirements of the Directive to be assessed. It shall, to the extent necessary for such assessment, cover the design, manufacture and operation of the product. It shall contain:

   — a general description of the equipment,

   — conceptual design and manufacturing drawings and schemes of components, sub-assemblies, circuits, etc.,

   — descriptions and explanations necessary for the understanding of said drawings and schemes and the operation of the equipment,

   — a list of the standards applied in full or in part, and descriptions of the solutions adopted to meet the safety aspects of the Directive where the standards have not been applied,

   — results of design calculations made, examinations carried out, etc.,

   — test reports.

4. The manufacturer or his authorized representative shall keep a copy of the declaration of conformity with the technical documentation.

5. The manufacturer shall take all measures necessary to ensure that the manufacturing process guarantees compliance of the manufactured equipment with the technical documentation referred to in Section 2 and with the requirements of the Directive applicable to such equipment.

ANNEX IX

MODULE: UNIT VERIFICATION

1. This module describes the procedure whereby the manufacturer ensures and declares that the equipment or protective system which has been issued with the certificate referred to in Section 2 conforms to the requirements of the Directive which are applicable to it. The manufacturer or his authorized representative in the Community shall affix the CE marking to the equipment or protective system and draw up a declaration of conformity.

2. The notified body shall examine the individual equipment or protective system and carry out the appropriate tests as set out in the relevant standard(s) referred to in Article 5, or equivalent tests, to ensure its conformity with the relevant requirements of the Directive.

   The notified body shall affix, or cause to be affixed, its identification number on the approved equipment or protective system and shall draw up a certificate of conformity concerning the tests carried out.

3. The aim of the technical documentation is to enable conformity with the requirements of the Directive to be assessed and the design, manufacture and operation of the equipment or protective system to be understood.

   The documentation shall contain:

   — a general description of the product;

   — conceptual design and manufacturing drawings and layouts of components, sub-assemblies, circuits, etc.;

   — descriptions and explanations necessary for the understanding of said drawings and layouts and the operation of the equipment or protective system;

   — a list of the standards referred to in Article 5, applied in full or in part, and descriptions of the solutions adopted to meet the essential requirements of the Directive where the standards referred to in Article 5 have not been applied;

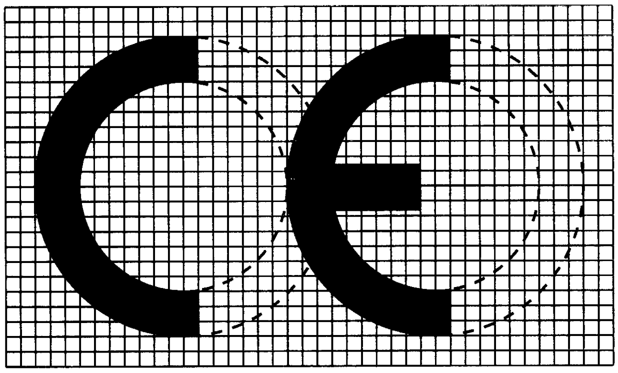
   — results of design calculations made, examinations carried out, etc.;

   — test reports.

ANNEX X

A. **CE Marking**

The CE conformity marking shall consist of the initials 'CE' taking the following form:



If the marking is reduced or enlarged, the proportions given in the above graduated drawing must be respected.

The various components of the CE marking must have substantially the same vertical dimension, which may not be less than 5 mm.

This minimum dimension may be waived for small-scale equipment, protective systems or devices referred to in Article 1 (2).

B. **Content of the EC declaration of conformity**

The EC declaration of conformity must contain the following elements:

— the name or identification mark and the address of the manufacturer or his authorized representative established within the Community;

— a description of the equipment, protective system, or device referred to in Article 1 (2);

— all relevant provisions fulfilled by the equipment, protective system, or device referred to in Article 1 (2);

— where appropriate, the name, identification number and address of the notified body and the number of the EC-type-examination certificate;

— where appropriate, reference to the harmonized standards;

— where appropriate, the standards and technical specifications which have been used;

— where appropriate, references to other Community Directives which have been applied;

— identification of the signatory who has been empowered to enter into commitments on behalf of the manufacturer or his authorized representative established within the Community.

ANNEX XI

MINIMUM CRITERIA TO BE TAKEN INTO ACCOUNT BY MEMBER STATES FOR THE NOTIFICATION OF BODIES

1. The body, its director and the staff responsible for carrying out the verification tests shall not be the designer, manufacturer, supplier or installer of equipment, protective systems, or devices referred to in Article 1 (2) which they inspect, nor the authorized representative of any of these parties. They shall become involved neither directly nor as authorized representatives in the design, construction, marketing or maintenance of the equipment, protective systems or devices referred to in Article 1 (2) in question. This does not preclude the possibility of exchanges of technical information between the manufacturer and the body.

2. The body and its inspection staff shall carry out the verification tests with the highest degree of professional integrity and technical competence and shall be free from all pressures and inducements, particularly financial, which may influence their judgement or the results of the inspection, especially from persons or groups of persons with an interest in the result of verifications.

3. The body shall have at its disposal the necessary staff and possess the necessary facilities to enable it to perform properly the administrative and technical tasks connected with verification; it shall also have access to the equipment required for special verification.

4. The staff responsible for inspection shall have:

   — sound technical and professional training;

   — satisfactory knowledge of the requirements of the tests which they carry out and adequate experience of such tests;

   — the ability to draw up the certificates, records and reports required to authenticate the performance of the tests.

5. The impartiality of inspection staff shall be guaranteed. Their remuneration shall not depend on the number of tests carried out or on the results of such tests.

6. The body shall take out liability insurance unless its liability is assumed by the State in accordance with national law or the Member State itself is directly responsible for the tests.

7. The staff of the body shall be bound to observe professional secrecy with regard to all information gained in carrying out its tasks (except *vis-à-vis* the competent administrative authorities of the State in which its activities are carried out) under this Directive or any provision of national law giving effect to it.

13.9 Directive 1999/92/EC of the European Parliament and Council of December 16, 1999 regarding minimum requirements for improving health protection and safety of employees who may be endangered by a potentially explosive atmosphere (ATEX 137)

Date of issue 10/17/07 030360

DIRECTIVE 1999/92/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 16 December 1999

on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 137 thereof,

Having regard to the proposal from the Commission [1], submitted after consultation with the Advisory Committee on Safety, Hygiene and Health Protection at Work and the Safety and Health Commission for the Mining and Other Extractive Industries,

Having regard to the opinion of the Economic and Social Committee [2],

After consulting the Committee of the Regions,

Acting in accordance with the procedure referred to in Article 251 of the Treaty, in the light of the joint text approved by the Conciliation Committee on 21 October 1999 [3],

Whereas:

(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;

(2) Under the terms of that Article, those Directives are to avoid imposing administrative, financial and legal constraints in a way which would hold back the creation and development of small and medium-sized undertakings;

(3) The improvement of occupational safety, hygiene and health is an objective which should not be subordinated to purely economic considerations;

(4) Compliance with the minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres is essential if workers' safety and health protection is to be ensured;

(5) This Directive is an individual Directive within the meaning of Article 16(1) of Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work [4]; therefore, the provisions of the said Directive, in particular those relating to worker information, to the consultation and participation of workers and to the training of workers, are also fully applicable to cases in which workers are potentially at risk from explosive atmospheres, without prejudice to more restrictive or specific provisions contained in this Directive;

(6) This Directive constitutes a practical step towards the achievement of the social dimension of the internal market;

(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;

(8) Explosion protection is of particular importance to safety; whereas explosions endanger the lives and health of workers as a result of the uncontrolled effects of flame and pressure, the presence of noxious reaction products and consumption of the oxygen in the ambient air which workers need to breathe;

(9) The establishment of a coherent strategy for the prevention of explosions requires that organisational measures complement the technical measures taken at the workplace; Directive 89/391/EEC requires the employer to be in possession of an assessment of the risks to workers' health and safety at work; this requirement is to be regarded as being specified by this Directive in that it provides that the employer is to draw up an explosion protection document, or set of documents, which satisfies the minimum requirements laid down in this Directive and is to keep it up to date; the explosion protection document includes the identification of the hazards, the evaluation of risks and the definition of the specific measures to be taken to safeguard the health and safety of workers at risk from explosive atmospheres, in accordance with Article 9 of Directive 89/391/EEC; the explosion protection document may be part of the assessment of the risks to health and safety at work required by Article 9 of Directive 89/391/EEC;

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(1) OJ C 332, 9.12.1995, p. 10 and OJ C 184, 17.6.1997, p. 1.
(2) OJ C 153, 28.5.1996, p. 35.
(3) Opinion of the European Parliament of 20 June 1996 (OJ C 198, 8.7.1996, p. 160) confirmed on 4 May 1999 (OJ C 279, 1.10.1999, p 55), Council Common Position of 22 December 1998 (OJ C 55, 25.2.1999, p. 45), Decision of the European Parliament of 6 May 1999 (OJ C 279, 1.10.1999, p. 386). Decision of the European Parliament of 2 December 1999 and Council Decision of 6 December 1999.
(4) OJ L 183, 29.6.1989, p. 1.
(5) OJ L 100, 19.4.1994, p. 1.

(10) An assessment of explosion risks may be required under other Community acts; whereas, in order to avoid unnecessary duplication of work, the employer should be allowed, in accordance with national practice, to combine documents, parts of documents or other equivalent reports produced under other Community acts to form a single 'safety report';

(11) The prevention of the formation of explosive atmospheres also includes the application of the substitution principle;

(12) Coordination should take place when workers from several undertakings are present at the same workplace;

(13) Preventive measures must be supplemented if necessary by additional measures which become effective when ignition has taken place; maximum safety can be achieved by combining preventive measures with other additional measures limiting the detrimental effects of explosions on workers;

(14) Council Directive 92/58/EEC of 24 June 1992 on the minimum requirements for the provision of safety and/or health signs at work (ninth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) [1] is fully applicable, in particular to places immediately contiguous to hazardous areas, where smoking, crosscutting, welding and other activities introducing flames or sparks may interact with the hazardous area;

(15) Directive 94/9/EC divides the equipment and protective systems which it covers into equipment groups and categories; this Directive provides for a classification by the employer of the places where explosive atmospheres may occur in terms of zones and determines which equipment and protective systems groups and categories should be used in each zone,

HAVE ADOPTED THIS DIRECTIVE:

SECTION I

GENERAL PROVISIONS

Article 1

Object and scope

1. This Directive, which is the 15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC, lays down minimum requirements for the safety and health protection of workers potentially at risk from explosive atmospheres as defined in Article 2.

2. This Directive shall not apply to:

(a) areas used directly for and during the medical treatment of patients;

(b) the use of appliances burning gaseous fuels in accordance with Directive 90/396/EEC [2];

(c) the manufacture, handling, use, storage and transport of explosives or chemically unstable substances;

(d) mineral-extracting industries covered by Directive 92/91/EEC [3] or Directive 92/104/EEC [4];

(e) the use of means of transport by land, water and air, to which the pertinent provisions of the international agreements (e.g. ADNR, ADR, ICAO, IMO, RID), and the Community Directives giving effect to those agreements, apply. Means of transport intended for use in a potentially explosive atmosphere shall not be excluded.

3. The provisions of Directive 89/391/EEC and the relevant individual Directives are fully applicable to the domain referred to in paragraph 1, without prejudice to more restrictive and/or specific provisions contained in this Directive.

Article 2

Definition

For the purposes of this Directive, 'explosive atmosphere' means a mixture with air, under atmospheric conditions, of flammable substances in the form of gases, vapours, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture.

SECTION II

OBLIGATIONS OF THE EMPLOYER

Article 3

Prevention of and protection against explosions

With a view to preventing, within the meaning of Article 6(2) of Directive 89/391/EEC, and providing protection against explosions, the employer shall take technical and/or organisational measures appropriate to the nature of the operation, in order of priority and in accordance with the following basic principles:

— the prevention of the formation of explosive atmospheres, or where the nature of the activity does not allow that,

— the avoidance of the ignition of explosive atmospheres, and

— the mitigation of the detrimental effects of an explosion so as to ensure the health and safety of workers.

These measures shall where necessary be combined and/or supplemented with measures against the propagation of explosions and shall be reviewed regularly and, in any event, whenever significant changes occur.

[1] OJ L 245, 26.8.1992, p. 23.

[2] OJ L 196, 26.7.1990, p. 15. Directive as amended by Directive 93/68/EEC (OJ L 220, 30.8.1993, p. 1).

[3] OJ L 348, 28.11.1992, p. 9.

[4] OJ L 404, 31.12.1992, p. 10.

Article 4

Assessment of explosion risks

1. In carrying out the obligations laid down in Articles 6(3) and 9(1) of Directive 89/391/EEC the employer shall assess the specific risks arising from explosive atmospheres, taking account at least of:

— the likelihood that explosive atmospheres will occur and their persistence,

— the likelihood that ignition sources, including electrostatic discharges, will be present and become active and effective,

— the installations, substances used, processes, and their possible interactions,

— the scale of the anticipated effects.

Explosion risks shall be assessed overall.

2. Places which are or can be connected via openings to places in which explosive atmospheres may occur shall be taken into account in assessing explosion risks.

Article 5

General obligations

To ensure the safety and health of workers, and in accordance with the basic principles of risk assessment and those laid down in Article 3, the employer shall take the necessary measures so that:

— where explosive atmospheres may arise in such quantities as to endanger the health and safety of workers or others, the working environment is such that work can be performed safely,

— in working environments where explosive atmospheres may arise in such quantities as to endanger the safety and health of workers, appropriate supervision during the presence of workers is ensured in accordance with the risk assessment by the use of appropriate technical means.

Article 6

Duty of coordination

Where workers from several undertakings are present at the same workplace, each employer shall be responsible for all matters coming under his control.

Without prejudice to the individual responsibility of each employer as provided for in Directive 89/391/EEC, the employer responsible for the workplace in accordance with national law and/or practice shall coordinate the implementation of all the measures concerning workers' health and safety and shall state, in the explosion protection document referred to in Article 8, the aim of that coordination and the measures and procedures for implementing it.

Article 7

Places where explosive atmospheres may occur

1. The employer shall classify places where explosive atmospheres may occur into zones in accordance with Annex I.

2. The employer shall ensure that the minimum requirements laid down in Annex II are applied to places covered by paragraph 1.

3. Where necessary, places where explosive atmospheres may occur in such quantities as to endanger the health and safety of workers shall be marked with signs at their points of entry in accordance with Annex III.

Article 8

Explosion protection document

In carrying out the obligations laid down in Article 4, the employer shall ensure that a document, hereinafter referred to as the 'explosion protection document', is drawn up and kept up to date.

The explosion protection document shall demonstrate in particular:

— that the explosion risks have been determined and assessed,

— that adequate measures will be taken to attain the aims of this Directive,

— those places which have been classified into zones in accordance with Annex I,

— those places where the minimum requirements set out in Annex II will apply,

— that the workplace and work equipment, including warning devices, are designed, operated and maintained with due regard for safety,

— that in accordance with Council Directive 89/655/EEC [1], arrangements have been made for the safe use of work equipment.

The explosion protection document shall be drawn up prior to the commencement of work and be revised when the workplace, work equipment or organisation of the work undergoes significant changes, extensions or conversions.

The employer may combine existing explosion risk assessments, documents or other equivalent reports produced under other Community acts.

Article 9

Special requirements for work equipment and workplaces

1. Work equipment for use in places where explosive atmospheres may occur which is already in use or is made available in the undertaking or establishment for the first time before 30 June 2003 shall comply from that date with the minimum requirements laid down in Annex II, Part A, if no other Community Directive is applicable or is so only partially.

[1] OJ L 393, 30.12.1989, p. 13. Directive as amended by Directive 95/63/EC (OJ L 335, 30.12.1995, p. 28).

2. Work equipment for use in places where explosive atmospheres may occur which is made available in the undertaking or establishment for the first time after 30 June 2003 shall comply with the minimum requirements laid down in Annex II, Parts A and B.

3. Workplaces which contain places where explosive atmospheres may occur and which are used for the first time after 30 June 2003 shall comply with minimum requirements set out in this Directive.

4. Where workplaces which contain places where explosive atmospheres may occur are already in use before 30 June 2003, they shall comply with the minimum requirements set out in this Directive no later than three years after that date.

5. If, after 30 June 2003, any modification, extension or restructuring is undertaken in workplaces containing places where explosive atmospheres may occur, the employer shall take the necessary steps to ensure that these comply with the minimum requirements set out in this Directive.

SECTION III

MISCELLANEOUS PROVISIONS

Article 10

Adjustments to the annexes

Purely technical adjustments to the annexes made necessary by:

— the adoption of Directives on technical harmonisation and standardisation in the field of explosion protection, and/or

— technical progress, changes in international regulations or specifications, and new findings on the prevention of and protection against explosions,

shall be adopted in accordance with the procedure laid down in Article 17 of Directive 89/391/EEC.

Article 11

Guide of good practice

The Commission shall draw up practical guidelines in a guide of good practice of a non-binding nature. This guide shall address the topics referred to in Articles 3, 4, 5, 6, 7 and 8, Annex I and Annex II, Part A.

The Commission shall first consult the Advisory Committee on Safety, Hygiene and Health Protection at Work in accordance with Council Decision 74/325/EEC (1).

In the context of the application of this Directive, Member States shall take the greatest possible account of the above-mentioned guide in drawing up their national policies for the protection of the health and safety of workers

Article 12

Information to undertakings

Member States shall, on request, endeavour to make relevant information available to employers in accordance with Article 11, with particular reference to the guide of good practice

Article 13

Final provisions

1. Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive not later than 30 June 2003. They shall forthwith inform the Commission thereof.

When Member States adopt these measures, they shall contain a reference to this Directive or shall be accompanied by such reference on the occasion of their official publication. The methods of making such reference shall be laid down by the Member States.

2. Member States shall communicate to the Commission the text of the provisions of domestic law which they have already adopted or adopt in the field governed by this Directive.

3. Member States shall report to the Commission every five years on the practical implementation of the provisions of this Directive, indicating the points of view of employers and workers. The Commission shall inform thereof the European Parliament, the Council, the Economic and Social Committee and the Advisory Committee on Safety, Hygiene and Health Protection at Work.

Article 14

This Directive shall enter into force on the day of its publication in the *Official Journal of the European Communities*.

Article 15

This Directive is addressed to the Member States.

Done at Brussels, 16 December 1999.

For the European Parliament	*For the Council*
The President	*The President*
N. FONTAINE	K. KEMILÄ

(1) OJ L 185, 9.7.1974, p. 15. Decision as last amended by the 1994 Act of Accession.

ANNEX I

CLASSIFICATION OF PLACES WHERE EXPLOSIVE ATMOSPHERES MAY OCCUR

Preliminary note

The following system of classification must be applied to places where precautions in accordance with Articles 3, 4, 7 and 8 are taken.

1. **Places where explosive atmospheres may occur**

A place in which an explosive atmosphere may occur in such quantities as to require special precautions to protect the health and safey of the workers concerned is deemed to be hazardous within the meaning of this Directive.

A place in which an explosive atmosphere is not expected to occur in such quantities as to require special precautions is deemed to be non-hazardous within the meaning of this Directive.

Flammable and/or combustible substances are considered as materials which may form an explosive atmosphere unless an investigation of their properties has shown that in mixtures with air they are incapable of independently propagating an explosion.

2. **Classification of hazardous places**

Hazardous places are classified in terms of zones on the basis of the frequency and duration of the occurrence of an explosive atmosphere.

The extent of the measures to be taken in accordance with Annex II, Part A, is determined by this classification.

Zone 0

A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.

Zone 1

A place in which an explosive atmosphere consisting of a mixture with air or flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.

Zone 2

A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Zone 20

A place in which an explosive atmosphere in the form of a cloud of combustable dust in air is present continously, or for long periods or frequently.

Zone 21

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.

Zone 22

A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Notes:

1. Layers, deposits and heaps of combustible dust must be considered as any other source which can form an explosive atmosphere.
2. 'Normal operation' means the situation when installations are used within their design parameters.

ANNEX II

A. MINIMUM REQUIREMENTS FOR IMPROVING THE SAFETY AND HEALTH PROTECTION OF WORKERS POTENTIALLY AT RISK FROM EXPLOSIVE ATMOSPHERES

Preliminary note

The obligations laid down in this Annex apply to:

— places classified as hazardous in accordance with Annex I whenever required by the features of workplaces, workstations, the equipment or substances used or the danger caused by the activity related to the risks from explosive atmospheres,

— equipment in non-hazardous places which is required for, or helps to ensure, the safe operation of equipment located in hazardous places.

1. Organisational measures

1.1. *Training of workers*

The employer must provide those working in places where explosive atmospheres may occur with sufficient and appropriate training with regard to explosion protection.

1.2. *Written instructions and permits to work*

Where required by the explosion protection document:

— work in hazardous places must be carried out in accordance with written instructions issued by the employer,

— a system of permits to work must be applied for carrying out both hazardous activities and activities which may interact with other work to cause hazards.

Permits to work must be issued by a person with responsibility for this function prior to the commencement of work.

2. Explosion protection measures

2.1. Any escape and/or release, whether or not intentional, of flammable gases, vapours, mists or combustible dusts which may give rise to explosion hazards must be suitably diverted or removed to a safe place or, if that is not practicable, safely contained or rendered safe by some other suitable method.

2.2. If an explosive atmosphere contains several types of flammable and/or combustible gases, vapours, mists or dusts, protective measures shall be appropriate to the greatest potential risk.

2.3. Prevention of ignition hazards in accordance with Article 3 must also take account of electrostatic discharges, where workers or the working environment act as charge carrier or charge producer. Workers must be provided with appropriate working clothes consisting of materials which do not give rise to electrostatic discharges that can ignite explosive atmospheres.

2.4. Plant, equipment, protective systems and any associated connecting devices must only be brought into service if the explosion protection document indicates that they can be safely used in an explosive atmosphere. This applies also to work equipment and associated connecting devices which are not regarded as equipment or protective systems within the meaning of Directive 94/9/EC if their incorporation into an installation can in itself give rise to an ignition hazard. Necessary measures must be taken to prevent confusion between connecting devices.

2.5. All necessary measures must be taken to ensure that the workplace, work equipment and any associated connecting device made available to workers have been designed, constructed, assembled and installed, and are maintained and operated, in such a way as to minimise the risks of an explosion and, if an explosion does occur, to control or minimise its propagation within that workplace and/or work equipment. For such workplaces appropriate measures must be taken to minimise the risks to workers from the physical effects of an explosion.

2.6. Where necessary, workers must be given optical and/or acoustic warnings and withdrawn before the explosion conditions are reached.

2.7. Where required by the explosion protection document, escape facilities must be provided and maintained to ensure that, in the event of danger, workers can leave endangered places promptly and safely.

2.8. Before a workplace containing places where explosive atmospheres may occur is used for the first time, its overall explosion safety must be verified. Any conditions necessary for ensuring explosion protection must be maintained.

Such verification must be carried out by persons competent in the field of explosion protection as a result of their experience and/or professional training.

2.9. Where the risk assessment shows it is necessary:

— it must be possible, where power failure can give rise to the spread of additional risks, to maintain equipment and protective systems in a safe state of operation independently of the rest of the installation in the event of power failure,

— manual override must be possible in order to shut down the equipment and protective systems incorporated within automatic processes which deviate from the intended operating conditions, provided that this does not compromise safety. Only workers competent to do so may take such action,

— on operation of the emergency shutdown, accumulated energy must be dissipated as quickly and as safely as possible or isolated so that it no longer constitutes a hazard.

B. CRITERIA FOR THE SELECTION OF EQUIPMENT AND PROTECTIVE SYSTEMS

If the explosion protection document based on a risk assessment does not state otherwise, equipment and protective systems for all places in which explosive atmospheres may occur must be selected on the basis of the categories set out in Directive 94/9/EC.

In particular, the following categories of equipment must be used in the zones indicated, provided they are suitable for gases, vapours or mists and/or dusts as appropriate:

— in zone 0 or zone 20, category 1 equipment,

— in zone 1 or zone 21, category 1 or 2 equipment,

— in zone 2 or zone 22, category 1, 2 or 3 equipment.

ANNEX III

Warning sign for places where explosive atmospheres may occur, pursuant to Article 7(3):

Place where explosive atmospheres may occur

Distinctive features:

— triangular shape,

— black letters on a yellow background with black edging (the yellow part to take up at least 50 % of the area of the sign).

Member States may add other explanatory data if they wish.

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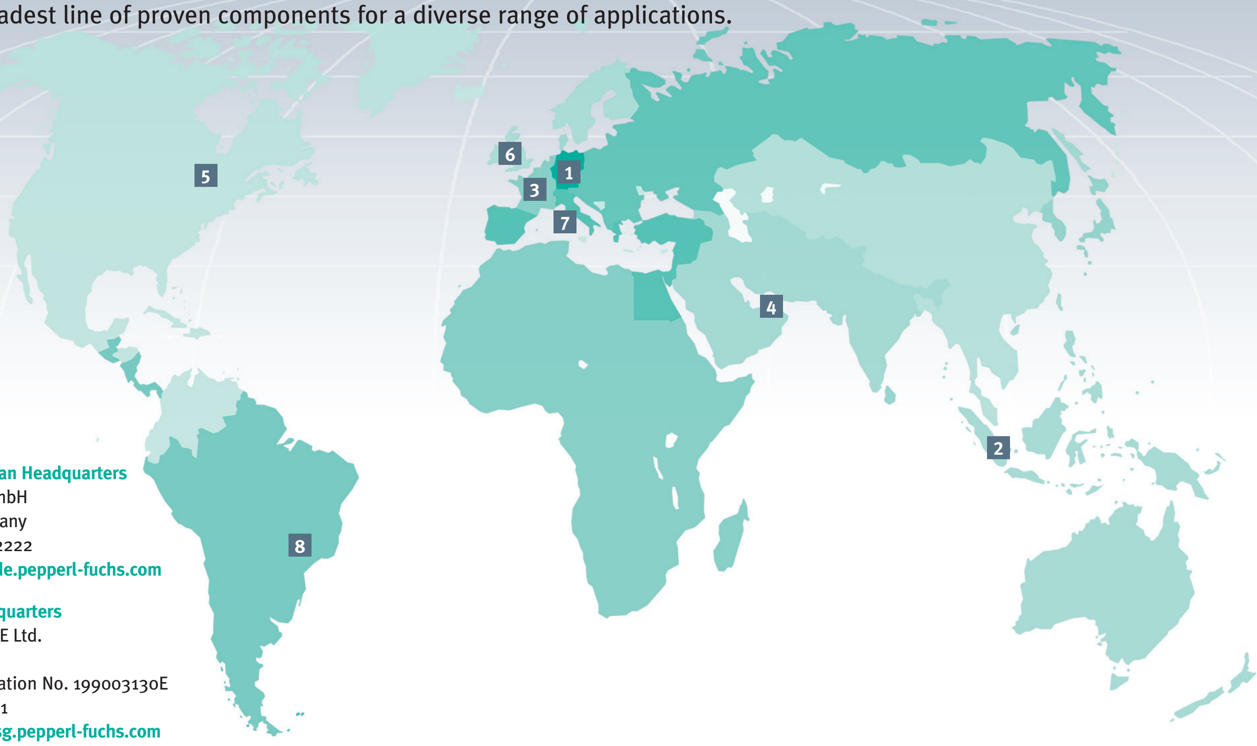

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