Explosion Protection in Europe

Electrical equipment
fundamentals, guidelines, standards

Jürgen Kuhlmei

EU Directive
94/9/EC
1999/92/EC

ATEX

ATmosphéres
EXplosibles

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"Explosion Protection in Europe" is a revised version of a book that previously appeared in the JUMO series of publications with the title "Explosion protection – Practical Fundamentals".

New directives from the European Union made a revision necessary, since the basic legislation and the standards have been changed. These changes are binding for all member states of the European Union.

However, the underlying reasons for explosions, and so the important fundamentals for explosion protection, remain unchanged.

This book is intended to be a helpful introduction to explosion protection. It provides advice about guidelines, regulations and standards that specify details on explosion protection.

Fulda, February 2003

Jürgen Kuhlmei

M.K. JUCHHEIM GmbH & Co, Fulda, Germany

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Contents

Contents

Contents

1 Conditions for an explosion

In industrial installations, such as chemical plants, paint-shops, sewage-treatment plants, power stations, and also in mining, flour mills, silos and woodworking factories, certain conditions may arise that create the risk of an explosion.

For this to happen, three factors must be fulfilled at the same time:

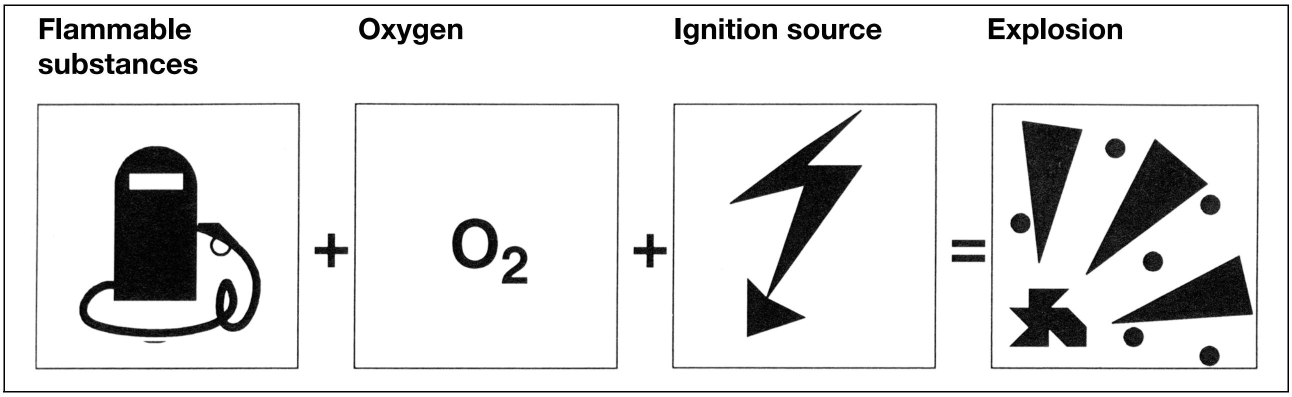


Fig. 1: Conditions for an explosion

Another important criterion is the concentration of flammable material and an oxygen-air mixture.

An explosion is a very fast form of combustion, whereby the flame front expands with a speed from 1 to 999 meters/second.

1.1 Flammable substances (examples)

- Gases (hydrogen, methane, butane, propane, natural gas ...),
- Liquids (petroleum, ether, benzole, toluol, methanol ...),
- Vapors (bubbling liquids – solvents ...),
- Solid materials (dusts – coal, flour, aluminium ...).

1.2 Oxygen

Oxygen is a part of the air we breathe, and so it is always present.

1.3 Ignition sources (examples)

Ignition sources provide the energy to initiate combustion.

- Flames (welding torch, heating installations),
- Hot surfaces (piping, heat chambers, hot-running bearings),
- Sparks (electric arcing, short-circuit, electrostatic discharge),
- Electrical plant or installations,
- Lightning strike,
- Chemical reactions.

1.4 Areas with an explosion hazard

The local and operational conditions may permit the development of an explosive atmosphere in dangerous quantities. If there is a risk that an explosive atmosphere may be produced, then it is mandatory that measures be taken for explosion protection.

1.5 Explosive atmosphere

A mixture of air and combustible gases, vapors, mists or dusts, including the normal additives, such as moisture, creates an explosive atmosphere. If this mixture is ignited under atmospheric conditions, the subsequent combustion reaction spreads automatically throughout the unburnt mixture.

For this purpose, atmospheric conditions are considered to be overall pressures of 0.8 to 1.1 bar and average temperatures from -20 to +60 °C.

1.6 Hazardous quantity

A quantity of gas, mist or vapor can be considered to be hazardous if 10 liters of the explosive mixture is present as one connected volume in a closed room. The size of the room does not matter.

In rooms smaller than 100 m^3, a volume of explosive atmosphere that is above 1/10,000 of the room volume is considered to be a hazardous quantity.

For dust, the ignitable concentration is in the range > 50 g/m^3 and a particle size < 100 µm.

1.7 Flash point

The flash point is defined in the standard EN 1127. It is the lowest temperature of a liquid at which combustible gases or vapors will be produced in such quantities that they will be instantly ignited by an effective ignition source (see also: DIN 51 755, DIN 22 719 and DIN 53 213).

Precise conditions are laid down for the determination and testing of the flash point.

If the temperature of the liquid is guaranteed always to be at least 5 to 15 °C below the flash point, then explosion protection is not required.

1.8 Ignition temperature of gaseous atmospheres

The ignition temperature of flammable gases or liquids is determined in a test rig. It is the lowest temperature of a heated surface at which the flammable substance (gas-air or vapor-air mixture) will just be ignited.

The flammable gases and vapors from flammable liquids are divided into temperature classes according to their ignition temperatures, equipment is divided into temperature classes according to the surface temperatures.

To avoid ignition, care must be taken to hold the surface temperature of the equipment below the ignition temperature.

1.9 Ignition temperature of dust

This is the lowest temperature, determined under specified test conditions, of a hot internal wall in an oven, at which it is possible to ignite the most easily ignitable mixture of air and dust (dust cloud) in the oven.

1.10 Smoldering temperature of dust

A dust layer on a hot piece of equipment can be ignited. The lowest surface temperature of the equipment that can cause ignition of the dust is known as the smoldering temperature. The thickness of the dust layer must be specified (EN 50 281-1-2).

1.11 Summary

Manufacturers of equipment for use in areas with an explosion hazard (Ex areas), and those who install and operate equipment in plant and areas in which there is an explosion hazard, must implement all measures required by the generally valid European laws and regulations in order to avoid an explosion.

As a general rule, other international standards may no longer be applied for installations within Europe.

2 Basic legislation

Those who install and operate plant, and the manufacturers of equipment, are obliged by law to observe measures for explosion protection.

The previous legislation on the basis of the EU Directive 76/117/EEC ceases to be valid after June 30th 2003.

Two new EU directives will now be decisive for explosion protection across Europe, and have the status of laws. All member states of the European Union are obliged to implement these directives in national law.

From July 1st 2003, only such equipment and protective devices may be placed on the market and only such installations may be commissioned that meet the following EU Directives for explosion protection.

2.1 EU Directive 94/9/EC

“Equipment and protective systems intended for use in potentially explosive atmospheres”

The directive is aimed at **manufacturers** of equipment and protective systems intended for use in potentially explosive atmospheres. It is also known under the name **ATEX 100a** (95a). ATEX stands for **AT**mosphéres **EX**plosibles.

The purpose of the directive is the protection of persons, domestic animals and property. Workers are particularly to be protected from the hazards resulting from the use of equipment and protective systems in potentially explosive areas.

What is covered?

“Equipment” means:	machines, apparatus, fixed or mobile devices, control elements and components thereof, instrumentation and control installations.
“Protective systems” means:	devices that are intended to stop incipient explosions immediately, e.g. flame propagation barriers, fire extinguishing barriers.

Further explanations can be found in “Guidelines for the Application of EU Directive 94/9/EC”.

2.2 EU Directive 1999/92/EC

“Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres”

This directive is aimed at **operators** of equipment, systems and protective devices intended for use in potentially explosive atmospheres. It is also known under the name **ATEX 118a** (137).

This directive incorporates requirements for the installation and maintenance of equipment and protective devices in potentially explosive areas. It follows the same protective aims as the EU Directive 94/9/EC.

2.3 Summary

EU Directive - ATEX
AT mosphéres EX plosibles

94/9/EC ATEX 100a/95a manufacturers	1999/92/EC ATEX 118a/137 operators

In Germany, the European Directives are implemented at the national level in § 11 of the Law on Equipment Safety (Gerätesicherheitsgesetz, GSG). The basic legislation is supplemented by the Explosion Protection Regulations (Explosionsschutz-Verordnungen, ExVo), Regulations for Flammable Liquids (Verordnung für brennbare Flüssigkeiten, VbF) and Regulations for Electrical Equipment in Potentially Explosive Areas (ElexV).

The Explosion Protection Regulations EX-RL (BGR 104) of the compulsory trade insurance institute provide assistance with the implementation of the German national workplace protection regulations for potentially explosive areas. However, as a rule it may be assumed that it is permissible to continue to operate existing installations which fulfilled the regulations in force at the time of their construction, unless there is a specific requirement for the retrofitting of particular components or areas.

A new factor is, that the European Directives now incorporate protection from dust explosion in legislation that applies to Europe as a whole.

Protection from dust explosion is specially concerned with areas that are endangered by dust, such as inside containers and silos and other apparatus (such as mills and mixers) or their surroundings, where dust is deposited. The first clearly identifiable dust explosion occurred in 1785, in Italy. In Germany, there was a catastrophic dust explosion at the Roland Mill in Bremen, in 1979, with 14 dead, 17 wounded, and damage amounting to about 50 million euros.

High safety requirements and tough regulations for protection from gas and dust explosion have always been observed in Germany. So the new legislation of the EU Directives can be implemented effectively.

Fig. 2: A mill after a dust explosion

2 Basic legislation

International	*International Electrotechnical Commission (IEC)* draws up documents Publication 79 "Electrical Apparatus for Potentially Explosive Atmospheres"	
Europe	*European Parliament and Council of the European Union* decree Directives according to the recommendations of the Commission	
	94/9/EC	The use of equipment and protective systems in potentially explosive areas
	1999/92/EC	Improving the safety and health protection of workers potentially at risk from explosive atmospheres
	European Electrical Standards Committee CENELEC produces European standards (see appendix)	
	EN 1127-1	Explosion protection
	EN 50 014	Electrical apparatus for areas with an explosion hazard
	EN 60 079	Electrical apparatus for areas with a gas explosion hazard
	EN 50 281	Electrical apparatus for use in areas with combustible dust
Germany	*Federal government* implements EU legislation as national legislation	
		Law on equipment safety Regulations
	German Electrotechnical Standards Commission DKE (DIN/VDE) harmonizes German standards with European standards	

Similar arrangements apply in the other member states of the European Union and Switzerland (VGSEG - regulations for equipment and protective systems in areas with an explosion hazard).

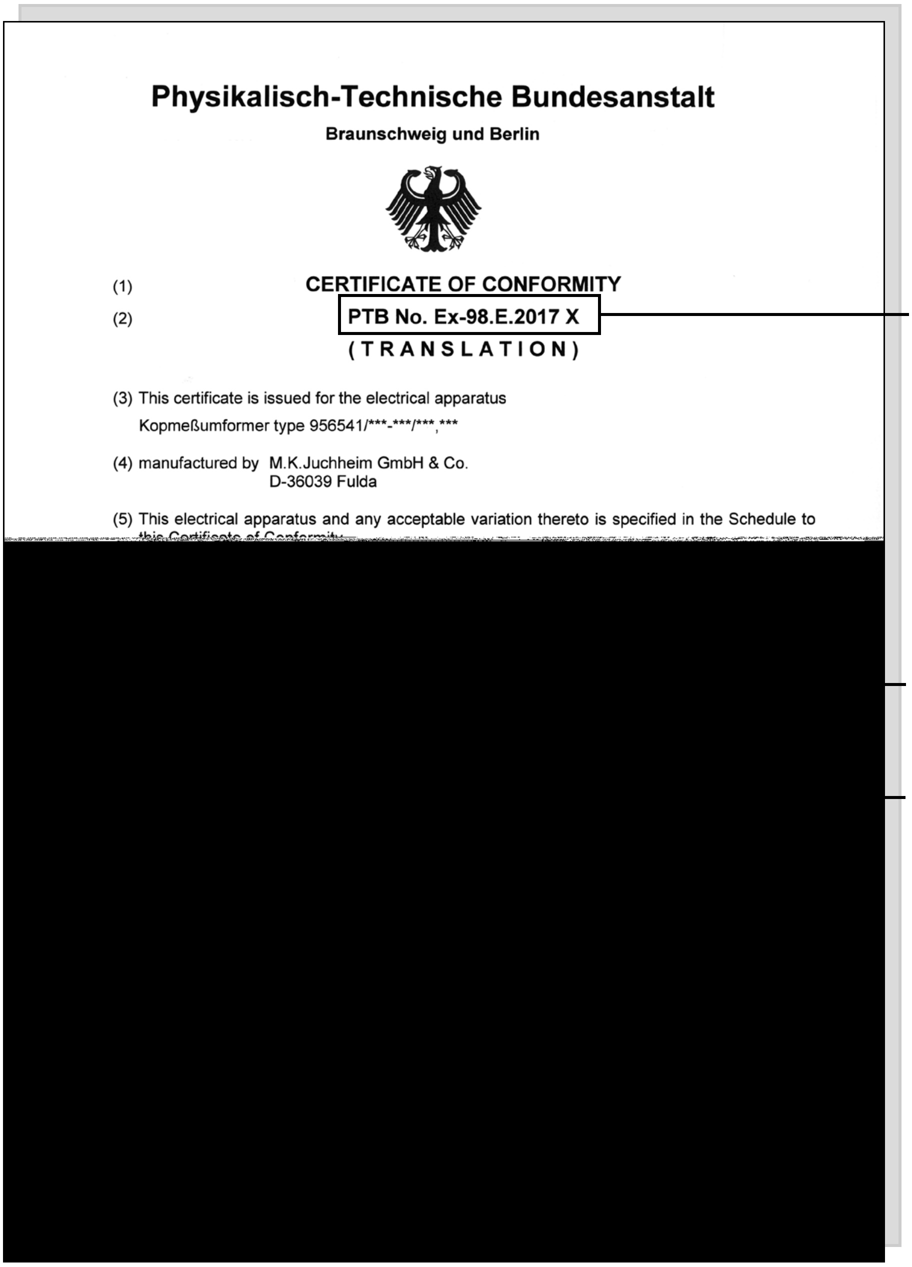
Table 1: Connections within the basic legislation for explosion protection

3 Placing electrical equipment on the market

Up to now, electrical equipment for explosion protection was tested by authorized test laboratories (e. g. PTB, BVS). The test laboratory concerned then issued a certificate of conformity. The manufacturer could then manufacture and deliver the product.

These certificates of conformity, which have been issued since 1995, are assigned to the “D” or “E” generation of regulations (see Fig. 3).

“D” or “E” stands for the valid test requirements that were applied.



Physikalisch-Technische Bundesanstalt

Braunschweig und Berlin

(1) **CERTIFICATE OF CONFORMITY**

(2) **PTB No. Ex-98.E.2017 X**

(T R A N S L A T I O N)

(3) This certificate is issued for the electrical apparatus
Kopmeßumformer type 956541/***-***/***,***

(4) manufactured by M.K.Juchheim GmbH & Co.
D-36039 Fulda

(5) This electrical apparatus and any acceptable variation thereto is specified in the Schedule to [redacted]

Fig. 3: Certificate of conformity PTB No. Ex-98.E.2017 X, following “old” legislation

Since 1994 it has already been possible to place equipment on the market and commission it in accordance with the EU Directive 94/9/EC and the new legislation. However, the directive also prescribes a new procedure, valid across Europe, for the “placing on the market” of products.

3 Placing electrical equipment on the market

The following section describes one of the possible procedures.

1. The manufacturer maintains an accredited quality assurance system for the production, final test and approval of his products for use in areas with an explosion hazard.
2. The manufacturer, or his representative within the European Union, applies to a test laboratory for an EC Type Examination (see Chapter 3.2) for his products. The test laboratory must be authorized by the government to conduct such examinations. Such authorized test laboratories are also known as “Notified Bodies”.
3. The manufacturer, or his representative within the European Union, produces a Declaration of Conformity (see Chapter 3.4) and implements the CE marking of the product (see EU Directive 94/9/EC - Annex).

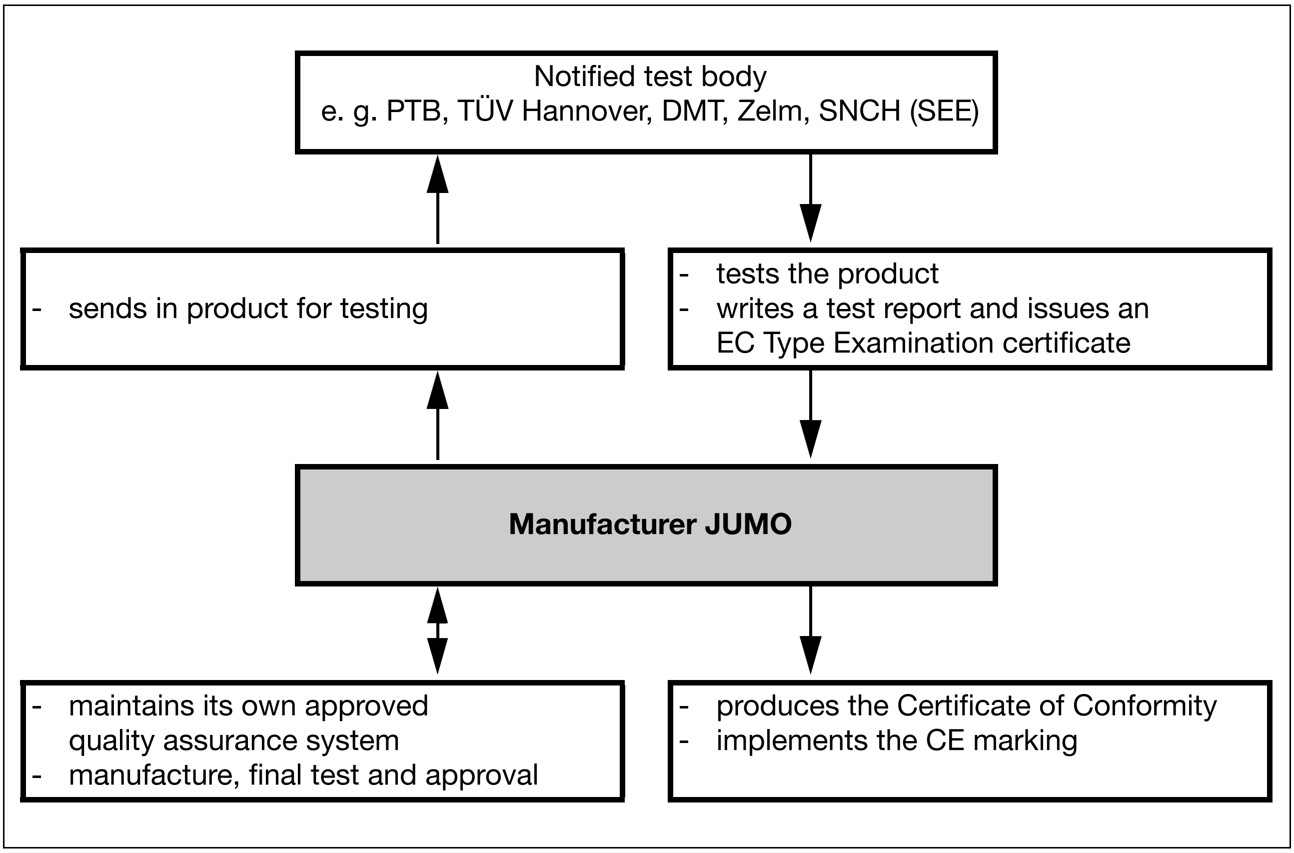


Fig. 4: Test procedure and “Placing on the market”

3 Placing electrical equipment on the market

3.1 Quality assurance in production

The manufacturer is obliged to let his quality assurance system for the area of production of equipment for explosion protection be audited by a notified body (certification authority) of his choice. This is intended to ensure that the products for which a type examination certificate has been produced are also manufactured to consistent levels of quality and safety.

The certification of a production operation to EN ISO 9001 (version 2000) can be used as a basis here. But according to legislative requirements, this certification is not enough by itself. There are further requirements applicable to the production of equipment for explosion protection. So additional certification of the production areas is therefore mandatory.

Translation

(1) **PRODUCTION QUALITY ASSESSMENT NOTIFICATION**

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

(3) Notification Number

TÜV 99 ATEX 1454 Q

(4)

Product Category	Protective Principle
Manufacturing and Distribution of instruments for measurement and control	Flameproof enclosures Increased safety Intrinsic safety

The EC-Type Examination Certificates based on this notification are listed by the notified body.

(5) Applicant: M. K. Juchheim GmbH & Co.
Moltkestraße 13-31
D-36039 Fulda

(6) Manufacturer: M. K. Juchheim GmbH & Co.
Moltkestraße 13-31
D-36039 Fulda

(7) The TÜV NORD CERT GmbH & Co. KG, TÜV CERT-Certification Body, notified body number N° 0032 in accordance with Article 9 of the Council Directive 94/9/EC of March 23, 1994, notifies the applicant that the manufacturer has a production quality system which complies with Annex IV of the Directive.

(8) This notification is based on audit report N° YEX 170 747 issued 2002-05-23. This notification can be withdrawn if the manufacturer no longer satisfies to the requirements of Annex IV.
Results of periodical production quality reassessments are a part of this notification.

(9) In accordance with Article 10 (1) of the Directive 94/9/EC the CE marking shall be followed by the identification number 0032 of the notified body TÜV NORD CERT GmbH & Co. KG.

TÜV NORD CERT GmbH & Co. KG
TÜV CERT-Zertifizierungsstelle
Am TÜV 1
D-30519 Hannover
Tel.: 0511 986-1470
Fax: 0511 986-2555

Hannover, 2002-06-30

Validity to 2005-06-29

First Certification 1999-06-30

Head of the Certification Body

TÜV NORD CERT

TÜV CERT A4 07.01 10.000 Lö

This notification may only be reproduced without any change.
Excerpts or changes shall be allowed by the TÜV NORD CERT GmbH & Co. KG

Fig. 5: Certificate TÜV 99 ATEX 1454 Q "Approval of the quality assurance system"

3.2 EC Type Examination

Type examination by a notified body (see Chapter 3.5) is prescribed for equipment and protective systems intended for use in the explosion protection Zone 0 and/or Zone 1 or Zone 20 and/or Zone 21 (see Chapter 7).

The notified body checks the technical documentation and the samples of the products concerned. It writes a test report and issues a type examination certificate.

snch

GRAND-DUCHE DE LUXEMBOURG

Société Nationale de Certification et d'Homologation S.à r.l.

EC-TYPE EXAMINATION CERTIFICATE

Equipment or Protective System Intended for use in Potentially explosive atmospheres Directive 94/9/EC

EC-Type Examination Certificate Number:	**SEE 01 ATEX 3225**
Equipment or Protective System:	**Resistance thermometer JUMO 902820/***/***362*****
Manufacturer:	**M.K. JUCHHEIM GmbH & Co. JUMO Mess- und Regeltechnik Moltkestraße 13-31 D-36039 Fulda**

This equipment or protective system and any acceptable variation thereto is specified in the schedule to this certificate and the documents therein referred to.

Société Nationale de Certification et d'Homologation S.à r.l, notified body no. 0499, in accordance with Article 9 of the Council Directive 94/9/EC of 23 March 1994, certifies that this equipment or protective system has been found to comply with the Essential Health and Safety Requirements relating to the design and construction of equipment or protective systems intended for use in potentially explosive atmospheres given in Annex II to the Directive.

The examination and test results are recorded in confidential report n° **01-IK-0244.02.**

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

EN 50014 : 1997 + A1 + A2 – General requirements
EN 50020 : 1994 – Intrinsic safety "i"
EN 50284:1999 / EN 50281-1-1:1998 / EN 50281-1-2:1998

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

This EC Type examination certificate relates only to the design, examination and tests of the specified equipment or protective system in accordance to the directive 94/9/EC. Further requirements of the Directive apply to the manufacturing process and supply of this equipment or protective system.These are not covered by this certificate.

The marking of the equipment or protective system shall include the following:

Ex II * G/D EEx ia IIC T1…T6 resp. EEx ib IIC T1…T6 T80°C…T400°C IP 5X…6X
(* Version with separating element: Category 1/2, without separating element: Category 2)

Page 1/2

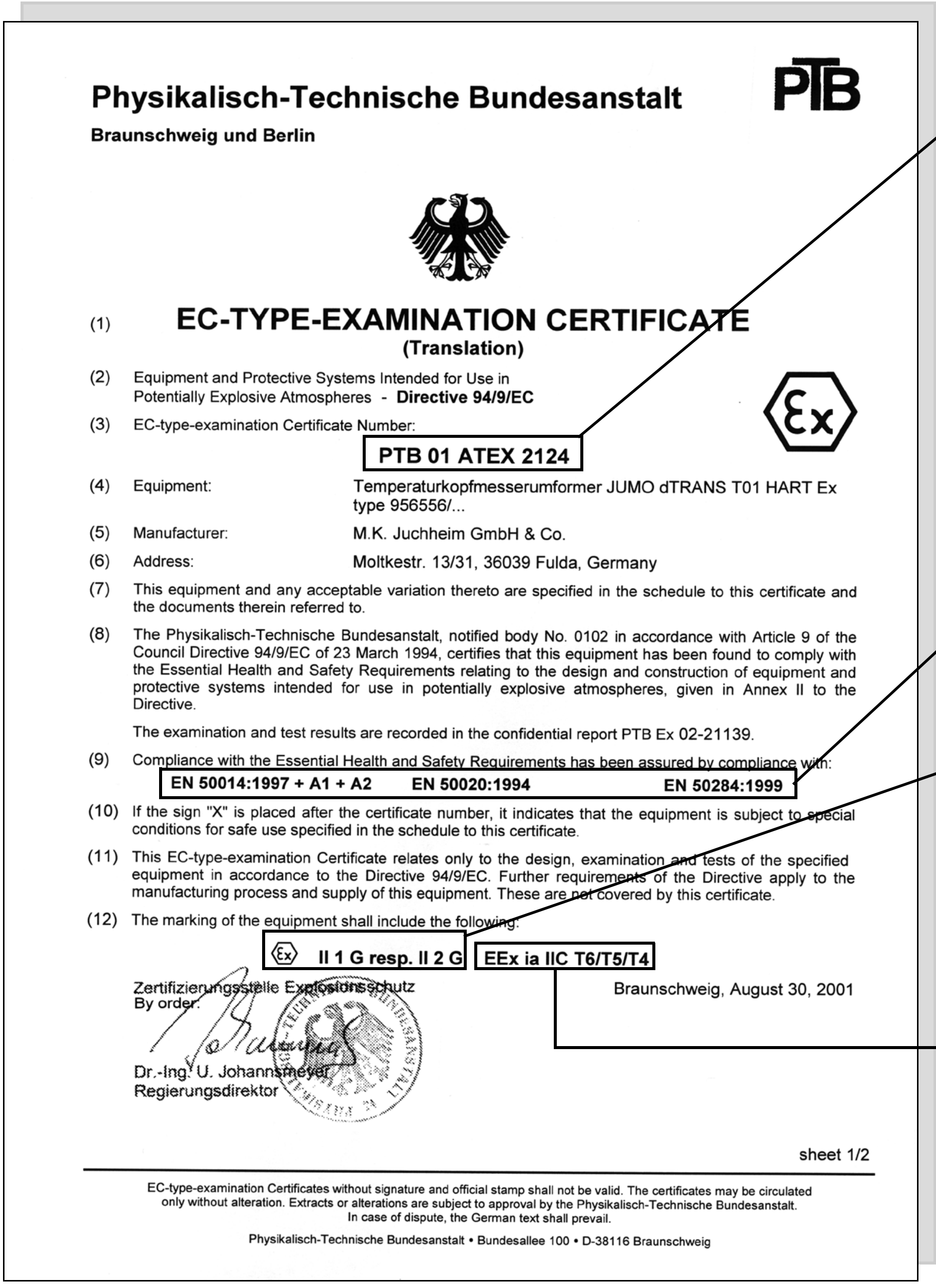
This certificate may only be reproduced in its entirety and without any change, schedule included.

Luxembourg, 13.02.2002

Camille GONDERINGER
Administrateur délégué

Société Nationale de Certification et d'Homologation S.à r.l.
Département SEE-Certification
11, route de Luxembourg B.P. 23
L-5201 SANDWEILER
(Int+352) 35 72 14-250 Fax (Int+352) 35 72 14-244

Fig. 6: Example of an EC type examination certificate: SEE 01 ATEX 3225 for resistance thermometers



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 01 ATEX 2124

(4) Equipment: Temperaturkopfmesserumformer JUMO dTRANS T01 HART Ex type 956556/...

(5) Manufacturer: M.K. Juchheim GmbH & Co.

(6) Address: Moltkestr. 13/31, 36039 Fulda, Germany

(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 02-21139.

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

EN 50014:1997 + A1 + A2 EN 50020:1994 EN 50284:1999

(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, examination and tests of the specified equipment in accordance to the Directive 94/9/EC. Further requirements of the Directive apply to the manufacturing process and supply of this equipment. These are not covered by this certificate.

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

Ex II 1 G resp. II 2 G **EEx ia IIC T6/T5/T4**

Zertifizierungsstelle Explosionsschutz
By order:

Braunschweig, August 30, 2001

Dr.-Ing. U. Johannsmeyer
Regierungsdirektor

sheet 1/2

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

Marking
PTB 01 ATEX 2124

PTB	testing body
01	year of certification
ATEX	tested to new European directive
2124	serial number

Standards

New marking
EX II 1 G / II 2 G

EX	Ex protection
II	equipment group
1 G	category

Marking
EEx ia IIC T6/T5/T4

EEx	European Ex protection
ia	protection type
IIC	explosion group
T6/T5/T4	temperature classes

Fig. 7: Example of an EC type examination certificate: PTB 01 ATEX 2124 for transmitters, to "new" legislation

The test is based on the European EN standards, which will be dealt with in following chapters. As a rule, the international IEC standards must not be applied within Europe.

3.2.1 Operating Instructions

The operating instructions are included in the type examination. There must be a set of operating instructions available for every piece of equipment or protective system, that includes the following details as a minimum requirement:

- The same details as those given by the marking of the equipment or protective system (apart from the serial number and year of manufacture).
- Details on
  - commissioning,
  - use,
  - assembly and dismantling,
  - maintenance,
  - installation,
  - marking of dangerous areas of pressure-relief devices (if applicable),
  - familiarization.
- Details that make it unambiguously clear whether the equipment or protective system can be used in the intended area and under the anticipated conditions without creating a hazard (note the category).
- Characteristic electrical parameters and pressures, maximum surface temperature and other limit values,
- Special conditions for use, if applicable,
- Warning of a possible improper use that experience has shown may occur,
- If required, specification of any tools that can be fitted to the equipment or protective system.

The operating instructions must be written in one of the languages of the European Union. They must be available both in the original language and in the language of the country in which the equipment or protective system is to be used.

3.3 Marking

The manufacturer must apply the relevant markings for the explosion protection and a CE mark (see Fig. 8) in accordance with the certified quality assurance and the type examination certificate.

The number of the notified body that audited the quality assurance system is added to the CE mark.

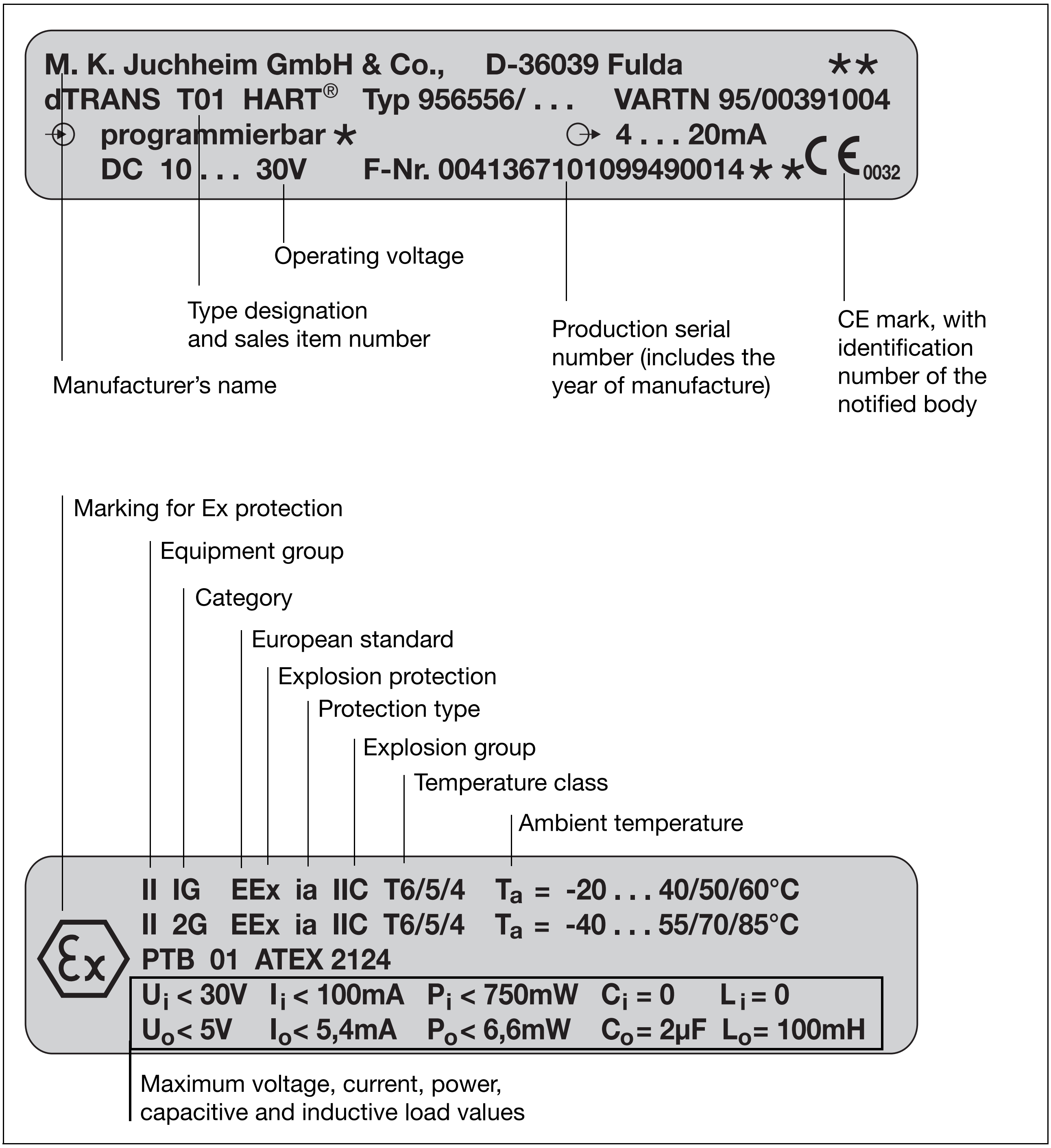


Fig. 8: Nameplates for a transmitter for Ex areas

JUMO Mess- und Regeltechnik AG
CH-8712 Stäfa

Resistance therm. 90.2820.7045

Ex II 1/2 G EEx ia IIC T6

Order No. 14363 / 020
Date of manuf. 47/2002
Protection tube constant 63.4 KW

SEE 01 ATEX 3224 / CE 0499

Observe the operating instructions
and data sheet / drawings!

Gas-Ex

JUMO Mess- und Regeltechnik AG
CH-8712 Stäfa

Resistance therm. 90.2820.7040

Ex II 1/2 D EEx ia IIC T80°C IP65

Pi ≤ 15mW / Ui ≤ 30V / Ii ≤ 100mA
Order No. 14574 / 030
Date of manuf. 50/2002

SEE 01 ATEX 3224 / CE 0499

Observe the operating instructions
and data sheet / drawings!

Dust-Ex

Fig. 9: Nameplates for resistance thermometers for Ex areas (Swiss subsidiary)

3.4 Declaration of Conformity

The declaration of conformity must include the following details:

- name and address of the manufacturer
  or his representative within the European Union
- description of the product
- regulations to which the product conforms
- number of the EC type examination certificate,
- name, identification number and address of the notified body
- standards applied
- legally binding signature

The certificate of conformity must be packed with every delivery of the product.

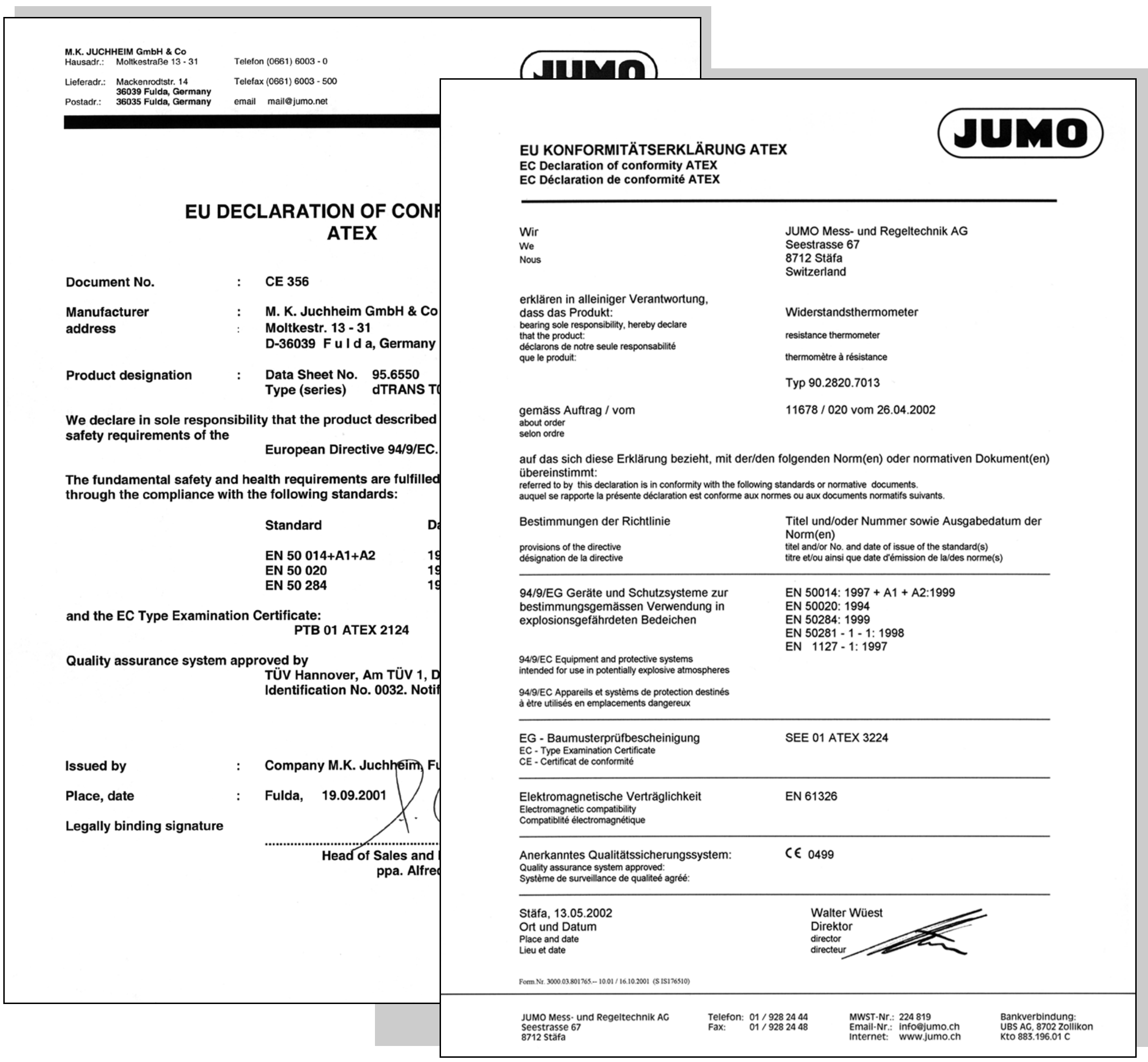


Fig. 10: Examples of EC conformity declarations

3.5 Notified European testing bodies

In Germany and other EU member states, there are notified bodies which are authorized to conduct testing and approval of electrical equipment or systems that are intended for use in areas with an explosion hazard. An EC type examination certificate that has been issued by one of these testing bodies must be recognized in all member states, even without supplementary testing.

Name	Country	ID No.
ISSEP Institut Scientifique des Services Publics	Belgium	0492
DEMKO Denmarks Elektriske Materialkontrol	Denmark	0539
PTB Physikalisch-Technische-Bundesanstalt	Germany	0102
DMT Deutsche Montan Technologie	Germany	0158
TÜV Hannover Technischer Überwachungsverein Hannover	Germany	0032
TÜV Produkt-Service Technischer Überwachungsverein Produkt-Service	Germany	0123
Zelm Ex Prüf- und Zertifizierungsstelle Firma Zelm	Germany	0820
INERIS Institut National de L' Environnement Industriel et des Risques	France	0080
LCIE Laboratoire Central des Industries Électriques	France	0081
EECS Electrical Equipment Certification Service Health and Safety Executive	Great Britain	0600
SCS Sira Certification Service	Great Britain	0518
CESI Centro Elettrotecnico Sperimentale Italiano	Italy	0722
SNCH Société Nationale de Certification et d' Homologation	Luxembourg	0499
KEMA KEMA Registered Quality BV	Netherlands	0344
NEMKO Norges Elektriske Materiellkontroll	Norway	0470
TÜV-A Technischer Überwachungsverein-Austria	Austria	0408
SP Sveriges Provnings- och Forskningsinstitut	Sweden	0402
LOM Laboratorio Oficial José Maria de Madariaga	Spain	0163

Table 2: Notified bodies (extract)

4 Obligations of manufacturers and operators

4.1 Manufacturers

The product that is actually delivered must conform to the prototype for which the type examination certificate was issued. Furthermore, every product item must be individually tested. In the course of the individual test, special care must be taken that every completed item of equipment is tested and every component section thereof that can affect explosion protection. Sample tests are not permissible.

The manufacturer confirms adherence to this procedure by issuing a certificate of conformity and by affixing the CE mark.

The manufacturer shall, for inspection purposes, allow the notified body access to the inspection, testing and storage premises. The manufacturer shall provide all relevant documentation on request.

The manufacturer shall preserve the technical documentation and certificate of conformity for at least 10 years after the last piece of equipment was manufactured.

4.2 Operators

The operator of electrical equipment and installations in areas with an explosion hazard also has obligations in accordance with the EU Directive 1999/92/EC.

The operator must take measures to enable operation without any hazard. These measures include drawing up an explosion protection document. This document demonstrates the classification of the place of operation into zones, a risk assessment, and the protective measures that have been taken.

The operator is responsible for ensuring that, in an area with an explosion hazard, only equipment that is accordingly approved and certified shall be used.

It is necessary that the equipment and installation is checked by a recognized expert before the initial commissioning and at regular intervals thereafter.

Any explosion that occurs must be immediately reported to the supervisory authorities. If any defects or faults are present that result in a hazard for workplace personnel or third parties, then the installation may no longer be operated.

5 Explosion protection measures

As a rule, it is necessary to implement protection measures in areas with an explosion hazard, in order to avoid explosions and to minimize their consequences. The aim is to prevent a dangerous, potentially explosive atmosphere arising (primary explosion protection) or being ignited (secondary explosion protection). In those cases where primary and secondary measures are ineffective or are not reliable enough, additional design measures (explosion protection through design) must be implemented.

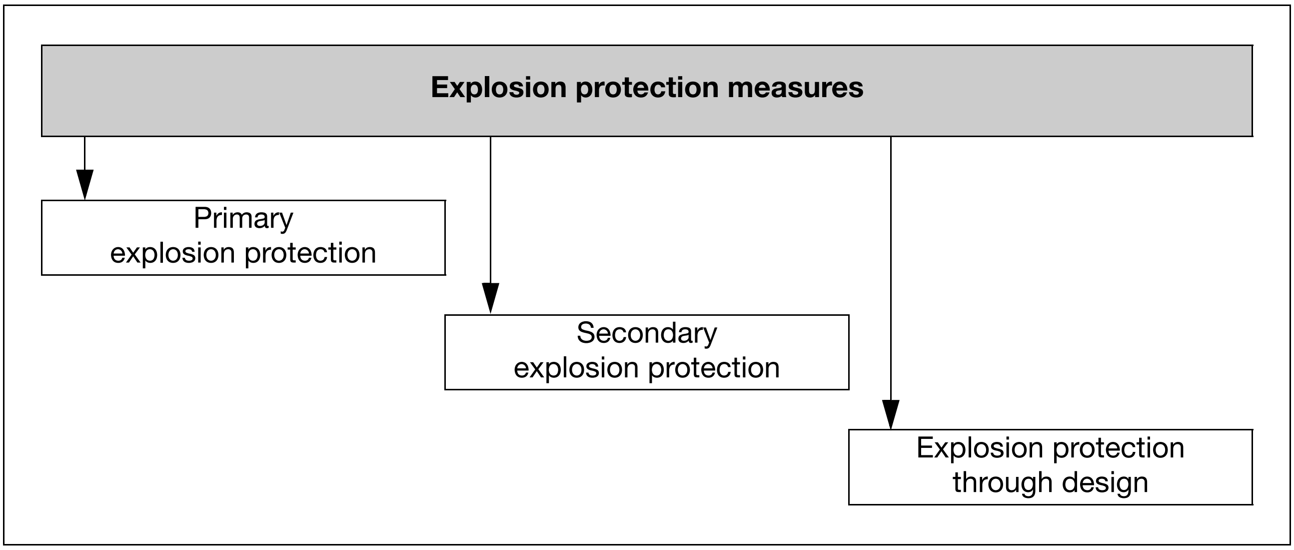


Fig. 11: Explosion protection measures

5.1 Primary explosion protection

Basically, the development of a dangerous, potentially explosive atmosphere can be prevented as follows.

Protection measures:

- Avoidance, replacement or limitation of flammable substances
- Use substances with a higher flash point
- Temperature limiting to prevent the flash point temperature being reached or exceeded
- Limiting and/or monitoring of concentrations
- Use gas warning devices
- Use non-flammable gases, e.g. nitrogen, carbon dioxide, rare gases, to create inert atmosphere
- Ventilation measures (natural or forced ventilation)
- Design measures (explosion-proof construction, explosion suppression, sealing, etc.)

Especially for dust:

- Surfaces on which dust can be deposited must be cleaned regularly
- Suction methods are to be preferred for cleaning
- Dust deposits should not be blown off by compressed air
- Use grounding to avoid accumulation of electrostatic charge
- Welding should not take place in the vicinity of apparatus and piping containing dust

5.2 Secondary explosion protection

Measures for secondary explosion protection must be taken if primary protection measures can only be used partially or not at all, and thus fail to provide adequate protection. Secondary explosion protection is concerned with avoiding ignition from the corresponding ignition sources.

Protection measures:

- Avoidance of ignition sources (flames, sparks, hot surfaces, etc.)
- Use of electrical equipment that does not create an ignition source
- Encapsulation of the ignition source, to isolate it from the surrounding atmosphere

5.3 Explosion protection through design

If primary and secondary measures are inadequate for reliable protection, then design measures must be implemented.

Protection measures:

- Explosion-proof construction
- Explosion pressure relief
- Explosion suppression
- Prevention of propagation of flame and explosion

6 Selection criteria for electrical equipment

Electrical equipment is used in a variety of areas with an explosion hazard, and with a variety of demands being made on the equipment. Detailed specifications are required to assess whether the equipment is suitable for the intended site.

To make such an assessment, electrical equipment is classified into groups, as before, and precisely marked (see Fig. 12).

The EU Directive 94/9/EC defines an extended marking (see Fig. 13).

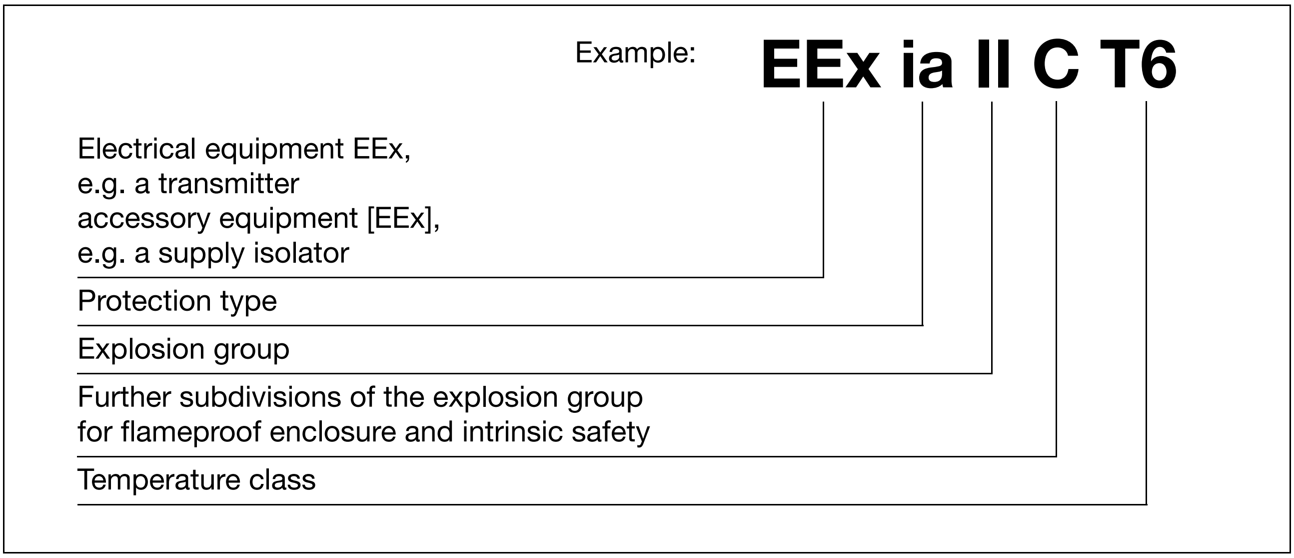


Fig. 12: Previous equipment marking

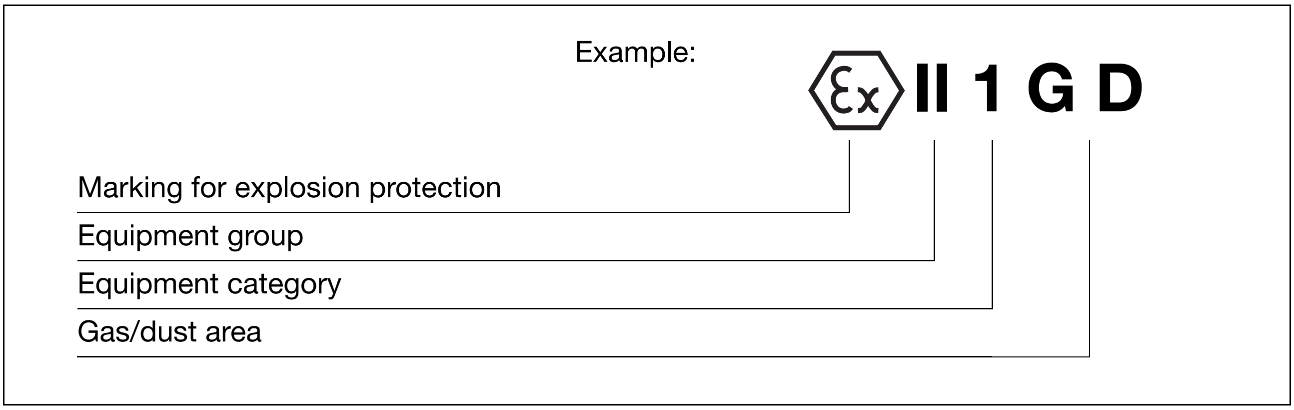


Fig. 13: Extended equipment marking

Equipment for use in dust areas is marked with the maximum surface temperature T_x of the equipment and the enclosure protection IP XX instead of the temperature class T1 to T6.

The individual selection criteria, such as protection types, categories, explosion groups and temperature classes are described in the following chapter.

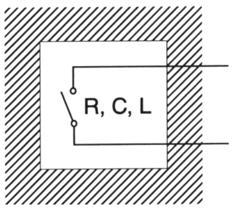
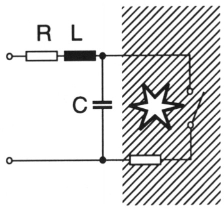
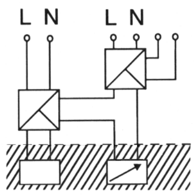
Protection type	Diagram (Ex area is cross-hatched)	Description of protection type
Intrinsic safety “i” EN 50 020		This type of protection has achieved considerable importance through the development of control and instrumentation technology. It does not refer to individual pieces of equipment or apparatus, but to circuits. These are built up from intrinsically safe circuit elements and the associated electrical equipment, which must fulfill clearly defined specifications.
Encapsulation “m” EN 50 028		The parts that could ignite a potentially explosive atmosphere, through sparking or heating, are encapsulated (potted) in a potting compound, so that the potentially explosive atmosphere cannot be ignited.
Intrinsically safe systems “i -SYST” EN 50 039		This standard is a supplement to EN 50 020 (Intrinsic safety “i”), whereby the requirements of that standard are to be applied, with the exception of the marking of electrical equipment in intrinsically safe systems laid down in Section 10. The term “intrinsically safe systems” is taken to mean the entirety of the equipment that is connected together and covered by a system description, and where the circuits that wholly or in part are to be used in areas with an explosion hazard are intrinsically safe circuits.
Non-sparking “n” EN 50 021		This standard is applied to electrical equipment and components of Group II Category 3 G (Zone 2). The equipment is incapable of igniting a potentially explosive atmosphere.

Table 3: Summary of protection types

6.2 Equipment with protection type “ia”/“ib”

Intrinsically safe electrical equipment (see Chapter 17) and intrinsically safe components of associated equipment must be assigned to the category “ia“ or “ib” according to EN 50 020.

Category “ia”	Category “ib”
Intrinsically safe circuits of electrical equipment in category “ia”. They must not generate any ignition in normal operation or in the worst case with **two faults**. (Basic design requirement of EN 50 020)	Intrinsically safe circuits of electrical equipment in category “ib”. They must not generate any ignition in normal operation or in the worst case with **one fault**. (Basic design requirement of EN 50 020)
A safety factor of 1.5 times the voltage or current or a combination of both is applied for spark ignition.	

Table 4: Equipment categories

Category “ia” is required for operating equipment in explosion zone 0.
Equipment in categories “ia” or “ib” can be used in explosion zones 1 and 2. The division into zones is explained in Chapter 7.

6.3 Explosion groups

Because of variations in the surrounding conditions on site, electrical equipment for areas with an explosion hazard is divided into groups. A distinction is made between explosion groups I and II.

Explosion group I	Explosion group II
Electrical equipment for use in mining operations with a firedamp risk, e. g. coal-mining: coal dust, methane gas	Electrical equipment for use in all areas with an explosion hazard, other than mining operations with a firedamp risk, e.g. the chemical industry: paints, acetylene

Table 5: Explosion groups

The wide range of applications involving various combustible materials and gases that have varying ignition energies results in a further subdivision into the groups IIA, IIB, and IIC.

Explosion group	IIA	IIB	IIC
Typical test gas	Propane	Ethylene	Hydrogen
Ignition energy required (microjoules, µJ)	high 260 µJ	medium 60 µJ	low 19 µJ

Table 6: Explosion groups IIA, IIB and IIC

Higher letters designate increasing explosion risk of the gases concerned. Hydrogen requires the least ignition energy, and so it presents the highest risk of an explosion. Equipment for explosion group IIC is therefore automatically suitable for use in group IIA or IIB. There is a special subdivision of group II for the protection types “Flameproof enclosure d” and “Intrinsic safety i” (see Chapter 6).

For **“Flameproof enclosure” (EN 50 018)**, the gases and vapors are divided according to the “Maximum Experimental Safe Gap” – MESG. This way of making a division is based on the principle that, if ignition occurs, only a small amount of energy can escape through a gap in the housing. This escaping energy is then smaller than the minimum energy required to ignite the surrounding explosive atmosphere.

Explosion group	IIA	IIB	IIC
Minimum Experimental Safe Gap (MESG)	> 0.9mm	0.5 to 0.9mm	< 0.5mm

Table 7: MESG

For **“Intrinsic safety” (EN 50 020)**, gases and vapors are divided according to the ratio of their minimum ignition current to the minimum ignition current for laboratory methane (Minimum Ignition Current - MIC). The procedure for determining the MIC ratio is described in Annex B of European standard EN 50 020. Annex A of EN 50 014 provides specific details for the division of gases and vapors.

Explosion group	IIA	IIB	IIC
MIC ratio	> 0.8	0.45 to 0.8	< 0.45

Table 8: Minimum ignition current

6.4 Surface temperature – temperature classes

In a potentially explosive atmosphere, a high surface temperature on an item of electrical equipment could cause heat ignition.

6.4.1 Explosion group I

For electrical equipment in explosion group I, there is a generally defined maximum surface temperature:

150 °C for layered coal dust deposits,
450 °C without coal dust deposits.

6.4.2 Explosion group II

For explosion group II there is a division into temperature classes, according to the ignition temperatures that have been determined for flammable materials. The electrical equipment is assigned to a temperature class according to its maximum surface temperature (EN 50 014).

Temperature class	Maximum permissible surface temperature of the equipment	Ignition temperature of the flammable material
T1	450 °C	>450 °C
T2	300 °C	>300 ≤ 450 °C
T3	200 °C	>200 ≤ 300 °C
T4	135 °C	>135 ≤ 200 °C
T5	100 °C	>100 ≤ 135 °C
T6	85 °C	> 85 ≤ 100 °C

Table 9: Explosion group II

- The details refer to an ambient temperature of +40 °C for the electrical equipment.
- The lowest ignition temperature of the corresponding potentially explosive atmosphere must be higher than the maximum surface temperature of the electrical equipment.
- The temperature limit for the electrical equipment must never be exceeded, not even in the event of a fault.

Example 1:
Petroleum fuels have ignition temperatures in the range from 220 to 300 °C, so that only equipment meeting temperature classes T3 to T6 may be used in such an atmosphere.

Example 2:
An item of electrical equipment has a surface temperature (in the event of a fault) of 140 °C. This means that it can only be used for temperature classes T1 to T3. So operation in an atmosphere containing carbon disulfide or ethyl ether is not possible (see Chapter 6.5).

6.5 Division of flammable gases and vapors into explosion groups and temperature classes

Temperature classes / Explosion group	T1 (450°C)	T2 (300°C)	T3 (200°C)	T4 (135°C)	T5 (100°C)	T6 (85°C)
IIA	Acetone (540°C) Ammonia (630°C) Benzene (555°C) Ethane (515°C) Ethyl acetate (460°C) Acetic acid (485°C) Carbon monoxide (605°C) Methanol (455°C) Propane (470°C) Toluene (535°C)	1,2-dichlorethane (440°C) Cyclohexanone (430°C) i-amyl acetate (380°C) n-butane (365°C) n-butyl alcohol (340°C)	Petroleum spirit (220 - 300°C) Diesel fuel oil (220 - 300°C) Aviation spirit (220 - 300°C) Heating fuel oil (220 - 300°C) n-hexane (240°C)	Acetalde-hyde (140°C)		
IIB	Town gas (560°C)	Ethyl alcohol (425°C) Ethylene (425°C) Ethylene oxide (440°C)	Ethyl glycol (335°C) Hydrogen sulfide (270°C)	Ethyl ether (180°C)		
IIC	Hydrogen (560°C)	Acetylene (305°C)				Carbon disulfide (95°C)

Table 10: Temperature classes / gas groups (extract)

7 Division into zones

Since a dangerous, potentially explosive atmosphere may not exist all the time within an area with an explosion hazard, these areas are divided into zones, according to the probability of the dangerous atmosphere being present. A classification in zones can be found in the “Regulations for electrical equipment in areas with an explosion hazard” and the European standards EN 60 079-10 (gas) and EN 50 281 (dust).

Ex zones	Covers areas in which a dangerous, potentially explosive atmosphere ...	This normally means ...	No effective ignition source ...
Gases, vapors, mists (EN 60 097-10)			
Zone 0	is present, either continuously or for lengthy periods [>1000 hours/year]	only inside containers, or the space inside apparatus	in fault-free operation, for rare operational faults or in the event of frequent operational faults
Zone 1	only occurs occasionally [10 - 1000 hours/year]	the immediate surroundings of Zone 0, of loading openings, filling/emptying devices, etc.	in fault-free operation or with frequent operational faults
Zone 2	infrequently, and then only for a short time [<10 hours/year]	the areas surrounding Zones 0, 1, or around flange connections	in fault-free operation
Dusts (EN 50 281)			
Zone 20	in the form of a cloud of combustible dust in the air, continuously, long-term, or frequently present [>1000 hours/year]	only inside apparatus, containers (mills, dryers, mixers), piping	in fault-free operation, with infrequent operational faults or with frequent operational faults
Zone 21	occasionally, from dust deposits being whirled up for a short time [10 - 1000 hours/year]	the surrounding area e. g. by dust removal or at filling stations or areas of dust deposits	in fault-free operation for whirled-up dust, and, with infrequent operational faults, for dust deposits
Zone 22	infrequently, and then only for a short time [<10 hours/year]	areas in which dust may emerge from leaky seals and form deposits	in fault-free operation

Table 11: Division into zones

The **installer** or **operator** of an installation must judge whether there is an explosion hazard within an area, and make the zoning accordingly.

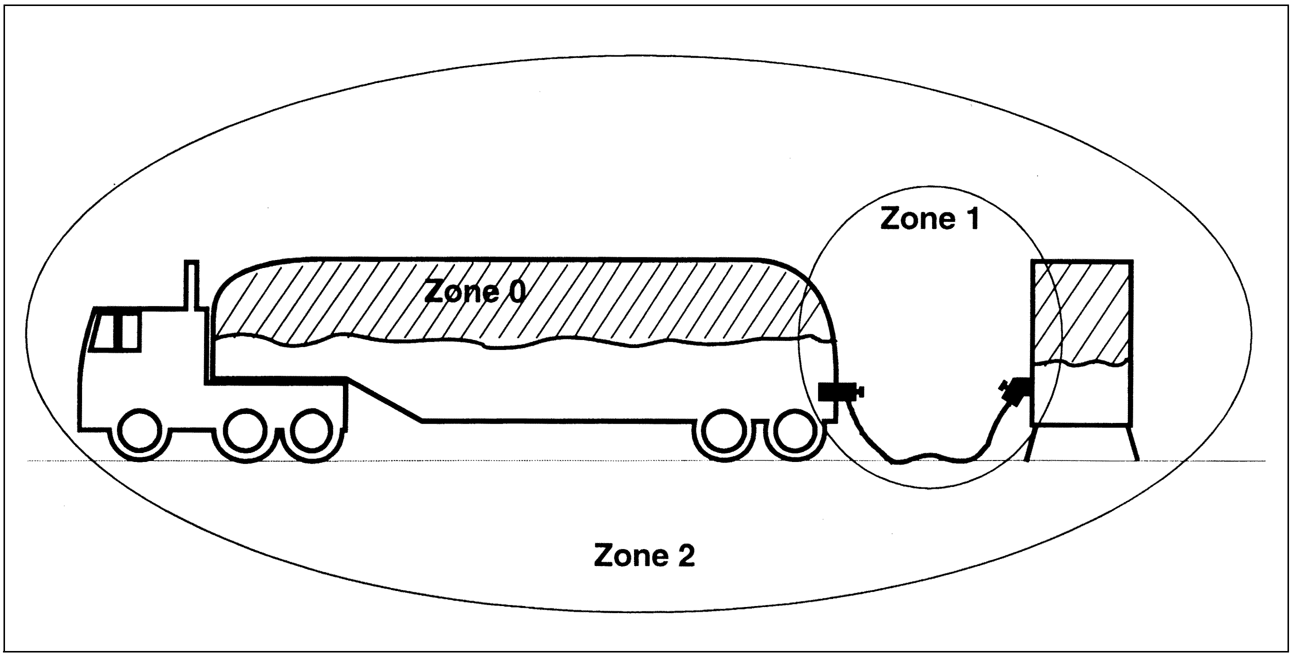


Fig. 14: Example: Transport of hazardous material

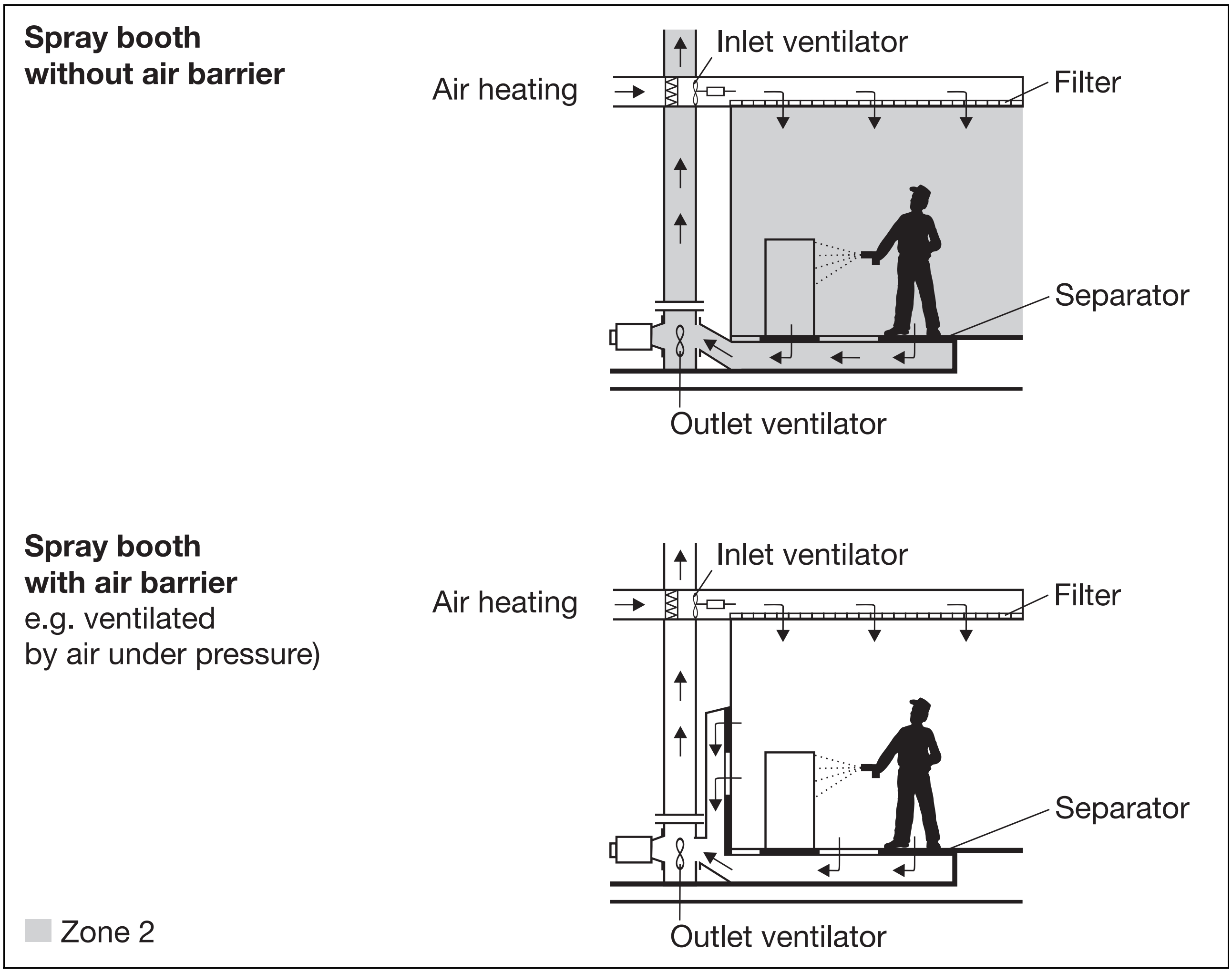


Fig. 15: Example: Using paint or lacquer

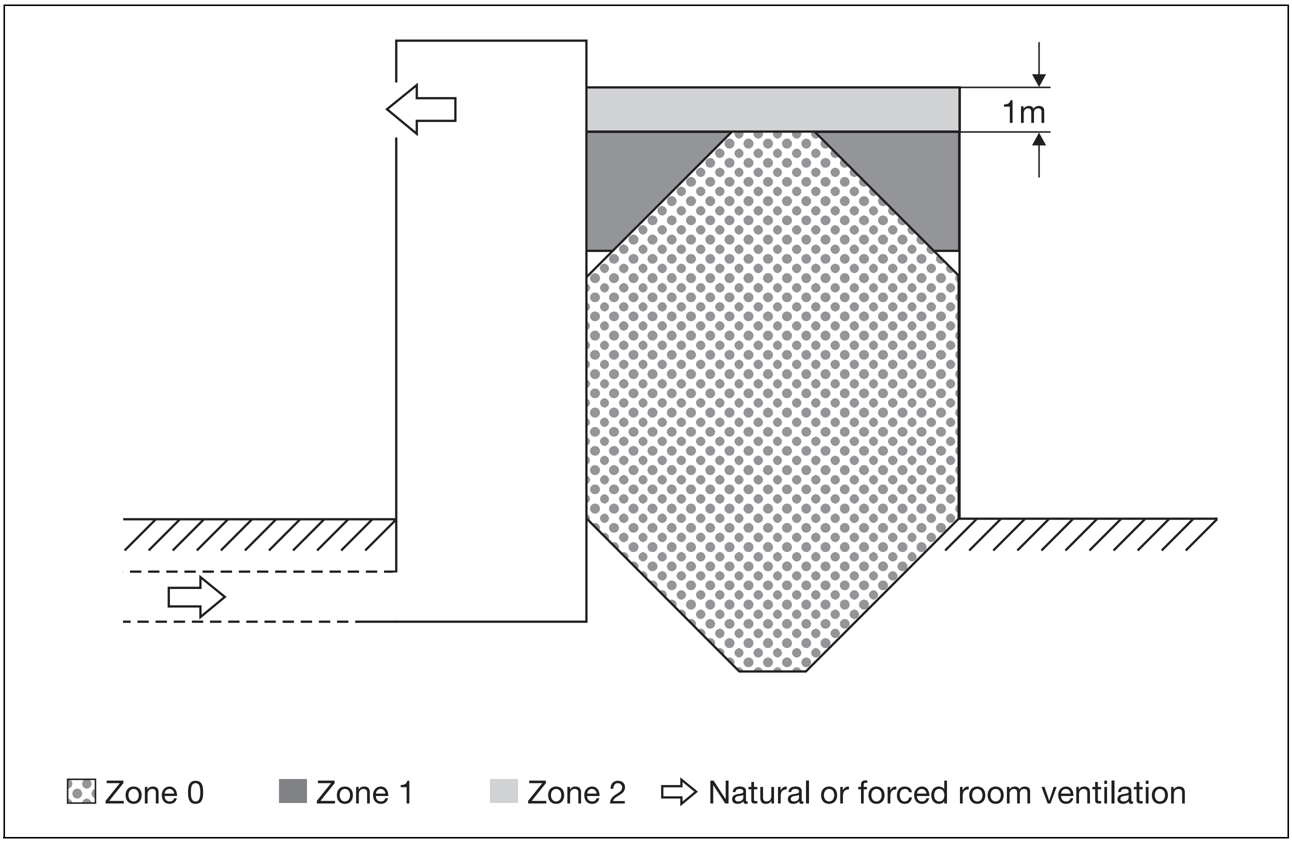


Fig. 16: Example: Waste water treatment plant – sludge tower with stairwell

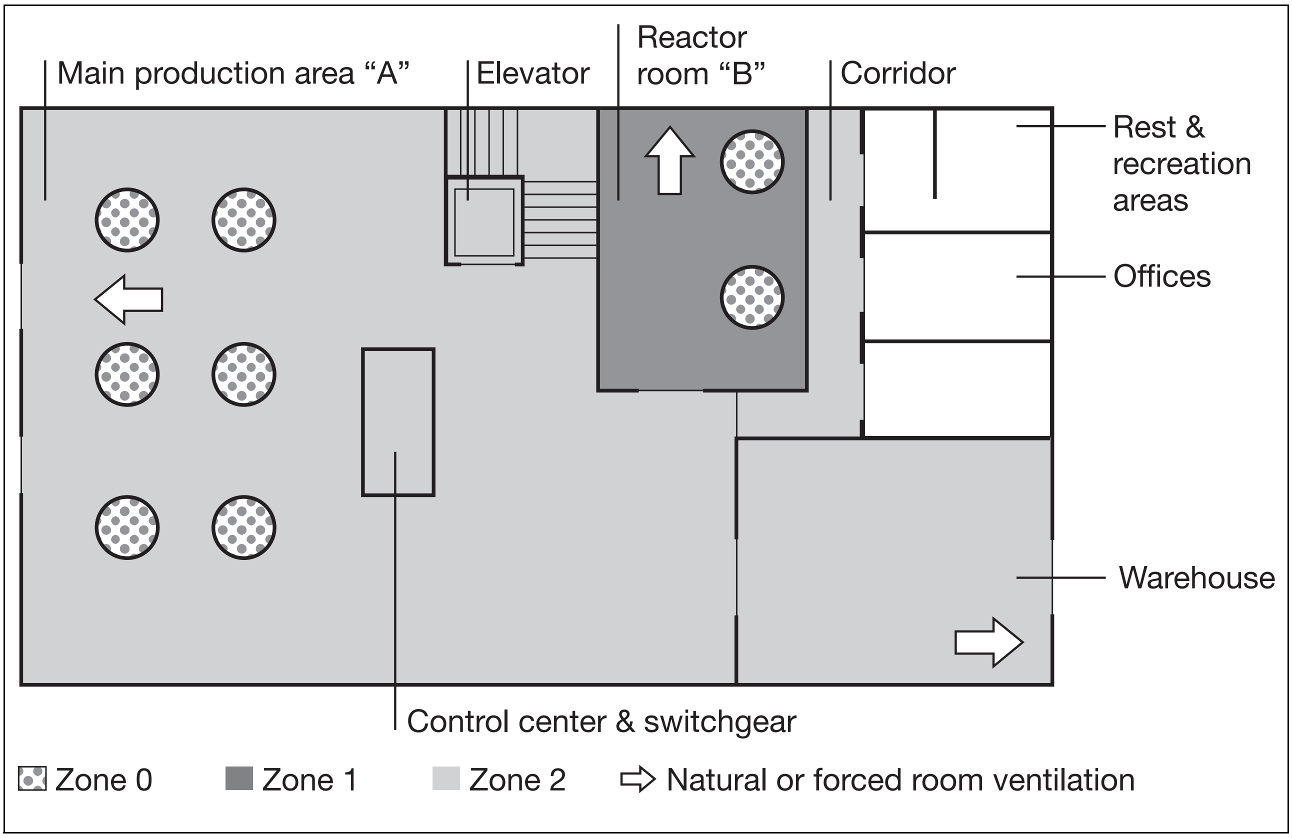
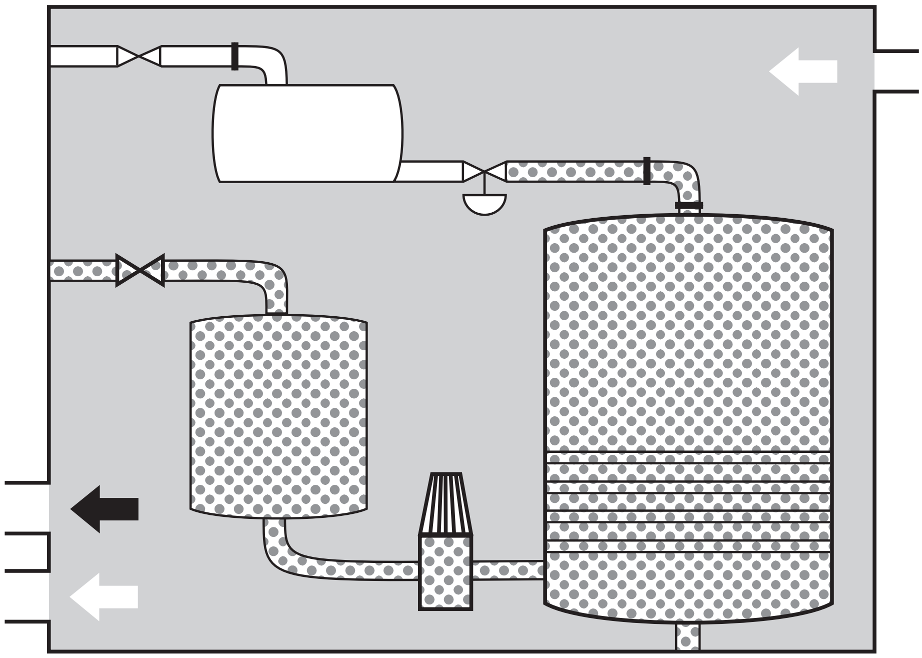
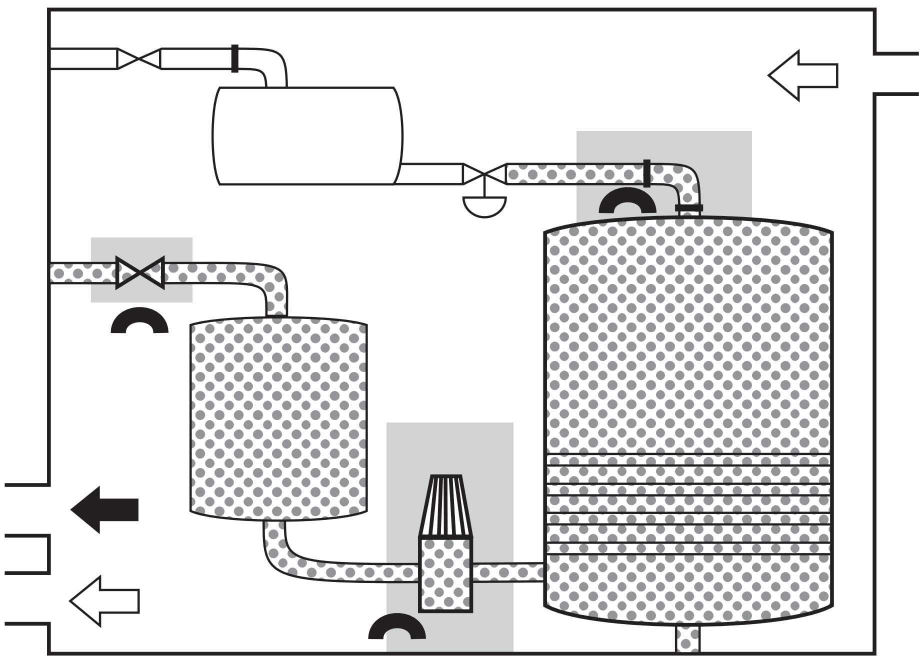


Fig. 17: Example: Production in the chemical industry

Without concentration monitoring



With concentration monitoring



Zone 0 Zone 2 Gas detector Blast ventilation Natural or forced room ventilation

Fig. 18: Example: Production plant with or without monitoring

8 Division into equipment groups and categories

According to the EU Directive 94/9/EC, equipment is also divided into equipment groups and categories. The assignment to an equipment group and a category forms part of the prescribed marking of the equipment (see Chapter 3.3). From this information, it can be seen quite clearly in which zones the equipment may be used.

Equipment group	**Cate-gory**	**Area of application: Ex areas, above and below ground for mining operations with a firedamp hazard**	
I	M1	Areas with continuous or lengthy periods of danger from mine gases (dust is also taken into consideration).	Very high safety level. Safe in the event of two independent faults. Two redundant protection measures. Continued operation must be ensured!
I	M2	Areas that may be endangered by mine gases (dust is also taken into consideration).	High safety level. It must be possible to switch off the equipment!
Equipment group	**Cate-gory**	**Area of application: Ex areas, but not in mining operations with a firedamp hazard**	
II	1G 1D	Gases, mists, vapors dusts	Very high safety level. Two independent faults. Two redundant protection measures.
II	2G 2D	Gases, mists, vapors dusts	High safety level
II	3G 3D	Gases, mists, vapors dusts	Normal safety level

Table 12: Division into Groups and Categories

9 Requirements for electrical equipment

This chapter provides a brief summary of the requirements for electrical equipment for use in the individual Ex zones. Further details can be found in the corresponding regulations.

9.1 Gas Zones (EN 60 079-14)

9.1.1 Ex Zone 0

- Here it is only permissible to use electrical equipment that meets a standardized explosion protection type (see Chapter 6).
- Electrical equipment and circuitry may be used in Zone 0 if they conform to EN 50 020, Category “ia”.
- Cables must be protected against mechanical damage, e. g. by using steel conduit.
- The cables and wires to the intrinsically safe circuits must have an identification marking.
- A supplementary potential equilibration bus-bar is required within Zone 0.
- The wiring together of two or more intrinsically safe circuits is not permitted unless a fresh certificate is issued by a notified body.
- As an alternative, explosion protection can be achieved through double safety (redundancy provided by two independent types of protection in accordance with EN 50 284).
- Where zones are separated by a protection sleeve, this must be made from, as a minimum, 1 mm thick chrome steel.

9.1.2 Ex Zone 1

- Here it is only permissible to use electrical equipment (apart from cables and wires) that meets a standardized protection type (see Chapter 6).
- Intrinsically safe equipment must be, as a minimum, to Category “ib”.
- The associated electrical equipment, such as power supply, safety barriers etc., must be installed outside the hazardous zone, unless they are protected against explosion through another type of protection.
- If two or more intrinsically safe circuits are wired together, the intrinsic safety of the entire circuit must be proved by calculation.
- It is permissible to connect equipment in intrinsically safe circuits.
  The equipment must not be overloaded with regard to current or voltage.
- Intrinsically safe connecting cables must not be routed together with other cables.
- The cables and wires to the intrinsically safe circuits must have an identification marking.

9.1.3 Ex Zone 2

- It is permissible to use equipment that is rated for use in Zones 0 or 1.
- Electrical equipment may also be used that is specifically designed for Zone 2 (equipment category 3) (e. g. protection type “n” to EN 50 021). This equipment must conform to the fundamental health and safety regulations. The manufacturer must, as a minimum, apply the internal production inspection procedure, as in the EU Directive, Annex II and VIII).
- All equipment is permitted that does not generate sparks, arcing or unacceptably high temperatures in fault-free operation. “Unacceptable” is a temperature that is as high as or exceeds the ignition temperature of the flammable materials concerned.
- The manufacturer must provide information about the relevant requirements (e.g. manufacturer’s certification, operating instructions).
- Equipment that internally generates sparks, arcing or unacceptably high temperatures in operation may be used, provided that:
  - the housing meets at least enclosure protection rating IP 54 and an internal underpressure of 300 Pa requires longer than 80 seconds to fall back to 150 Pa (smoke-proof housing) or
  - the equipment housing is pressurized by simple means.
- The electrical equipment must fulfill the following requirements:
  - equipment that includes bare active components and is used outdoors must have at least enclosure protection IP 54. In closed rooms, IP 40 is sufficient.
  - equipment for outdoors use that only has insulated components must have at least IP 44 protection, or IP 20 if used in closed rooms.
- Simple electrical equipment (see EN 50 020).

Equipment for use in Zone 2 requires the following statements by the manufacturer:

- The suitability for use in Zone 2
- Information on the maximum surface temperature that can arise in operation; classification in a temperature class.
- For lamps: information as to the suitability for outdoors use and/or mechanical vulnerability.

Note:
In an electrode system, equipment of category 3 must not be wired up to equipment of categories 1 or 2.

9.2 Dust Zones (EN 50 281)

9.2.1 Ex Zone 20

- It is only permissible to use equipment that has been specifically tested and certified for this zone (type examination).
- The housing must be dust-tight, with enclosure protection IP 6X to EN 60 529.
- The maximum permissible surface temperature must be stated.

9.2.2 Ex Zone 21

- A type examination is required.
- The housing must be dust-tight, with enclosure protection IP 6X to EN 60 529.

- The maximum permissible surface temperature must be stated.

9.2.3 Ex Zone 22

- Electrical equipment may be used that does not have any particular certification, provided that it conforms to a standardized protection type and meets the requirements below.
- The equipment must have at least enclosure protection IP 5X, or IP 6X where conductive dust is present.

9.3 Temperature limits for dust in Ex zones

- The surface temperature of the equipment must not be high enough to ignite whirling dust or dust that is deposited on the equipment.
  The following conditions must be fulfilled:
  a) The surface temperature must not exceed 2/3 of the ignition temperature in °C for the dust-air mixture concerned.
  b) On surfaces where a dangerous accumulation of dust that could smolder is not effectively prevented, the surface temperature must not rise above a level 75 °C below the smoldering temperature of the particular dust. Where layers occur that are thicker than 5 mm, a further reduction of the surface temperature is necessary.
  c) The applicable temperature is the lower value of those given by requirements a) and b).
  Remark: The relevant surface is the outer surface of the equipment, (see also EN 50 281-1-2).

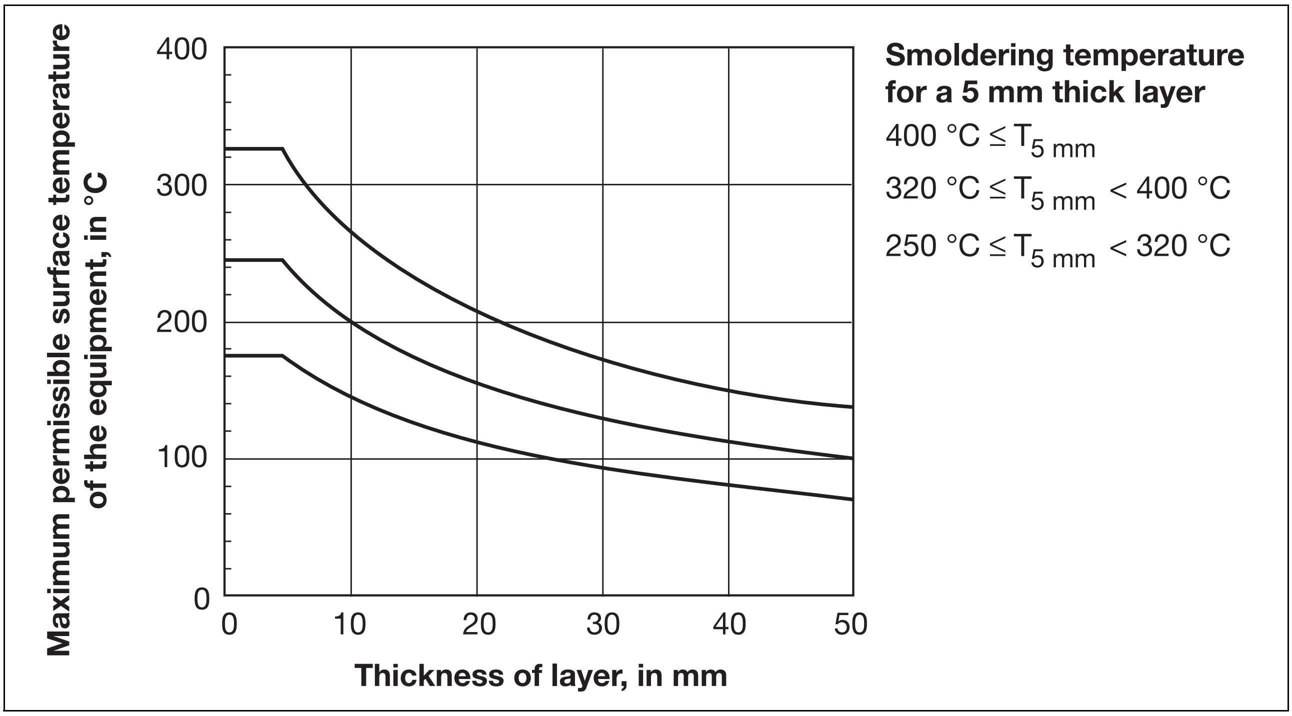


Fig. 19: Reduction of the maximum permissible surface temperature with increasing thickness of the dust deposit

10 Relationship between zones and categories

RL 1999/92/EC			RL 94/9/EC	
Zone division			Equipment requirement	
Definition			Category	
Gas	Dust	explosive atmosphere present	Gas	Dust
Zone 0	Zone 20	continuously, long-term, frequently	1G	1D
Zone 1	Zone 21	occasionally	2G	2D
Zone 2	Zone 22	infrequently, short periods	3G	3D

Table 13: Division into zones and categories

11 Enclosure protection

The housings of the electrical equipment that is used in the various zones must fulfill certain requirements for enclosure protection. The table shows the relationship between the codes (IP = Ingress Protection) and the protective measures. The basis is the EN 60 529 standard, that also describes the test criteria.

Example: IP 54
5 - = dust-protected
-4 = protection against splashed water

IP XX	First number		Second number
Code No.	**Contact protection**	**Foreign bodies**	**Water protection**
0	no protection	no protection	no protection
1	contact by back of hand	foreign bodies 50mm dia.	vertically dripping water
2	finger contact	foreign bodies 12.5mm dia.	angled (15°) dripping water
3	contact through tools	foreign bodies 2.5mm dia.	sprayed water up to 60°
4	wire contact	foreign bodies 1.0mm dia.	sprayed water from any direction (splashing)
5	wire contact	dust-protected	water jet
6	wire contact	dust-tight	strong jet, heavy seas
7	-	-	brief immersion in water
8	-	-	continuous immersion in water

Table 13: Protection measures for enclosures

12 Simple electrical equipment

EN 50 020 permits simple electrical equipment outside Ex Zone 0 under the following conditions:

- it must conform to the construction regulations of EN 50 020
- it must not have its own power supply (energy source)
- it must not contain any potential ignition source
- it must be operated within an intrinsically safe circuit
- it must be assigned to a temperature class

Energy sources	Passive components	Energy storage components
Thermocouple Photodiode max. values 1.5V; 100mA; 25mW	Switches Resistors Simple semiconductor components Potentiometers	Capacitors Inductors and coils

Table 14: Simple electrical equipment

13 Protection type Ex “i” intrinsic safety

The protection type Ex “i” is a secondary explosion protection measure. It is necessary if the generation of a potentially explosive atmosphere cannot be prevented. So the release of sufficient energy to ignite the explosive atmosphere must be prevented.

This energy arises:

- through the heating of the electrical equipment or the wiring
- through sparks produced by contacts in circuits opening and closing during operation or, in the event of a fault, by a short-circuit or short to ground
- through sparks generated by the discharge of electrostatic energy

These can be prevented by limiting the:

- voltage
- current
- power
- capacitance
- inductance

The limiting keeps any energy that is produced in operation or as the result of a fault so low that ignition does not occur.

13.1 Definitions according to EN 50 020

Intrinsically safe circuit
The energy in the circuit is so restricted that it is inadequate to cause ignition. This applies to spark generation as well as to thermal effects.
There are defined test conditions using specified explosive atmospheres. The testing covers both normal fault-free operation and specified fault conditions.

Electrical equipment
Electrical equipment is the entirety of electrical components and circuits or sections of circuits that is normally included within a single housing.

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

Associated electrical equipment
An item of electrical equipment in which not all circuits are intrinsically safe.

However, design restraints ensure that the non-intrinsically safe circuits cannot affect the intrinsically safe circuits. Such equipment is marked [EEx ia..] or [EEx ib..].

An item of associated electrical equipment may be used within the area with an explosion hazard (Ex area), provided that the appropriate type of protection (protection to EN 50 014) is applied. If the protection is inadequate, the equipment must be used outside the Ex area.

Example:
A transmitter (JUMO dTRANS T02) is not inside the Ex area, but it is connected to a thermocouple that is within the Ex area. Only the input circuit of the transmitter is intrinsically safe.

Fault-free operation
Intrinsically safe equipment or associated equipment in normal operation, whereby the electrical and mechanical parameters are within the specified ranges. The equipment must be used within the limits prescribed by the manufacturer.

Faults
Defect components and breaks, (damaged) insulation or faulty connections between components are considered to be faults if the intrinsic safety of a circuit depends upon them.

Remark:

- If a fault leads to one or more subsequent faults, then the primary and subsequent faults are treated as one single fault.
- The use of a spark testing apparatus in a circuit for creating breaks, short-circuits or ground shorts is considered to be a test of normal, fault-free operation.

Insensitive components/modules
Components and modules that do not become faulty during operation or storage in such a way that they can affect the intrinsic safety of the circuit. They are treated as insensitive during the intrinsic safety testing.

14 Intrinsically safe electrical equipment

The requirements of EN 50 020 Intrinsic Safety “i”, Section 6, must be followed inasmuch as they contribute to the protection of intrinsically safe equipment and the associated equipment. The general requirements of EN 50 014 must also be observed.

14.1 Wiring

Diameter	Wire cross-section	Max. permissible current for division into temperature classes		
		T1 - T4 and Group I	T5	T6
0.035 mm	0.000962 mm^2	0.53 A	0.48 A	0.43 A
0.050 mm	0.00196 mm^2	1.04 A	0.93 A	0.84 A
0.100 mm	0.00785 mm^2	2.10 A	1.90 A	1.70 A
0.200 mm	0.013 mm^2	3.70 A	3.30 A	3.00 A
0.350 mm	0.0962 mm^2	6.40 A	5.60 A	5.00 A
0.500 mm	0.196 mm^2	7.70 A	6.90 A	6.70 A

Table 15: Division of copper wiring into temperature classes

14.2 Component assembly

The components must be attached securely, so that the spacings cannot become smaller. If a potting compound is used, then care must be taken that the components and their connections are not damaged during the potting procedure.

14.3 Housing

In cases where intrinsic safety could be adversely affected by access to conductive components, an enclosure must be used that meets IP 20 of EN 60 529 or higher. In mining, enclosure protection rating IP 54 to EN 60 529 is required as a minimum, both above and below ground.

14.4 Connection terminals

The minimum spacing between intrinsically safe connection components and other components or bare conductors is 50 mm. Isolation by insulating walls or earthed metal walls is also possible.

14.5 Connectors

Connectors for intrinsically safe circuits must be separate to those for other (i.e. non-intrinsically safe) circuits, and incapable of being interchanged with them.

14.6 Air gaps, creepage distances, spacings inside potting compounds

Air gaps, creepage distances and spacings between bare parts inside potting compounds

- of an intrinsically safe circuit against one that is not intrinsically safe
- of two different intrinsically safe circuits
- of the same circuit
- of a circuit against earthed metallic parts

are not considered to be sensitive, provided that the requirements of Table 16 are fulfilled.

Voltage (peak value)	Air gaps	Spacing inside potting	Spacing through rigid insulation	Creepage distance in air	Creepage distance beneath the protective layer	Creepage current figure	
						ia	ib
10V	1.5mm	0.5mm	0.5mm	1.5mm	0.5mm	90	90
30V	2.0mm	0.7mm	0.5mm	2.0mm	0.7mm	90	90
60V	3.0mm	1.0mm	0.5mm	3.0mm	1.0mm	90	90
90V	4.0mm	1.3mm	0.7mm	4.0mm	1.3mm	90	90
190V	5.0mm	1.7mm	0.8mm	8.0mm	2.6mm	175	175
375V	6.0mm	2.0mm	1.0mm	10.0mm	3.3mm	175	175
550V	7.0mm	2.4mm	1.2mm	15.0mm	5.0mm	275	175
750V	8.0mm	2.7mm	1.4mm	18.0mm	6.0mm	275	175
1000V	10.0mm	3.3mm	1.7mm	25.0mm	8.3mm	275	175
1300V	14.0mm	4.6mm	2.3mm	36.0mm	12.0mm	275	175
1575V	16.0mm	5.3mm	2.7mm	40.0mm	13.3mm	275	175
3300V		9.0mm	4.5mm				
4700V		12.0mm	6.0mm				
9500V		20.0mm	10.0mm				
15600V		33.0mm	10.5mm				
For voltages above 1575V, there are no recommended values at present, apart from spacings. For voltages up to 10V it is not necessary to define a creepage current figure for insulating materials.							

Table 16: Air gaps, creepage distances and spacings (EN 50 020)

14.7 Earthing

In cases where it is necessary to earth an intrinsically safe circuit for functional and safety reasons, the earthing must be implemented in such a way that there are no detrimental effects to the intrinsic safety of the circuit.

14.8 Isolation

Electrical isolation must be ensured:

- between intrinsically safe circuits and chassis;
  minimum test voltage 500V rms AC, 1min.
- between intrinsically safe circuits and non-intrinsically safe circuits;
  minimum test voltage 1500V rms AC, 1min.

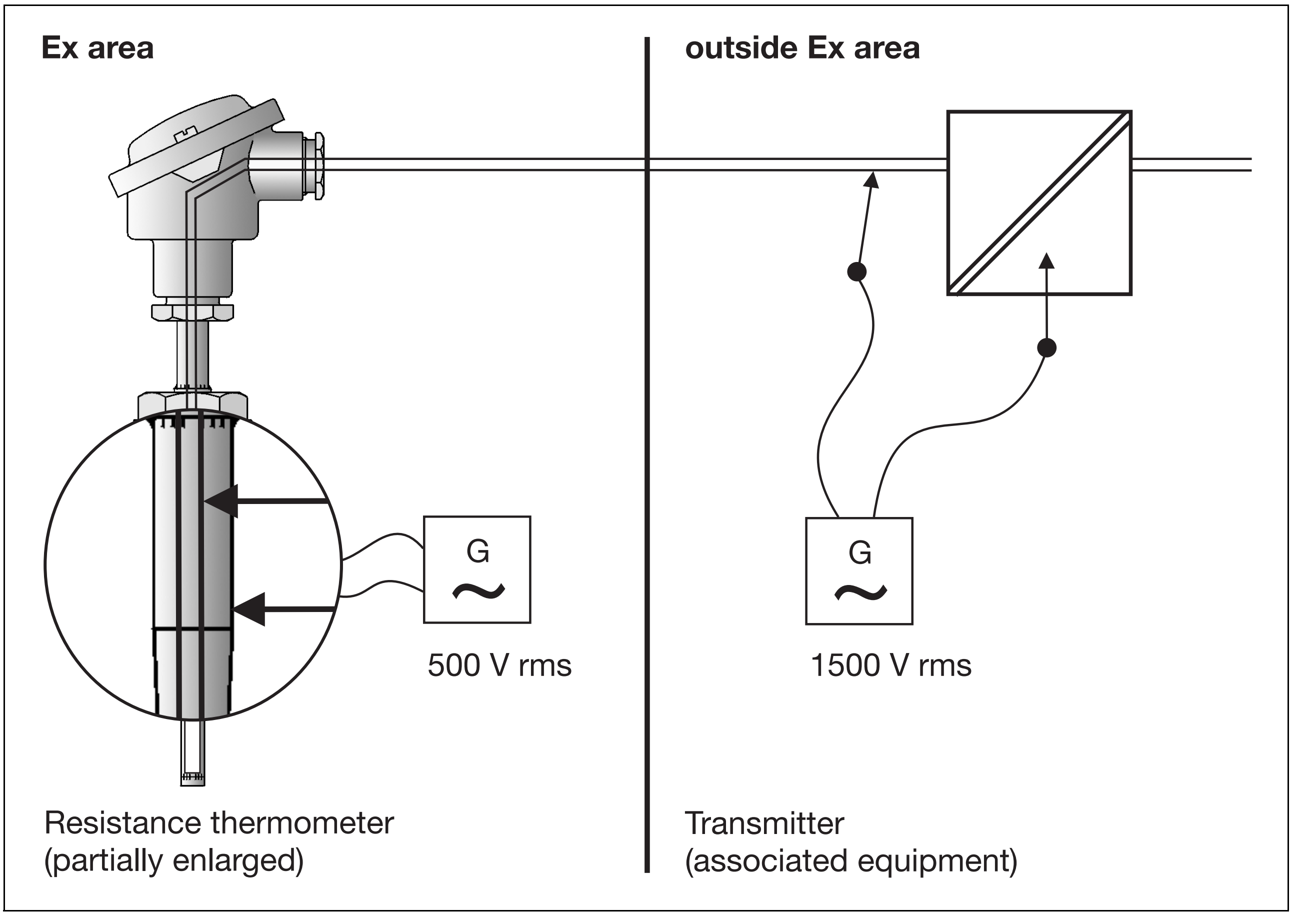


Fig. 20: Isolation requirements: example for an intrinsically safe circuit

14.9 Components on which the intrinsic safety depends

The design regulations for components are precisely defined in Section 7 of EN 50 020.
The most important are:

- maximum loading of the components is 2/3 of nominal ratings for voltage, current and power
- connectors shall not be capable of being interchanged
- semiconductors for voltage limiting must be able to carry 150% of the possible short-circuit current, without going open-circuit
- semiconductors for current limiting may only be used in category “ib”
- sensitive components must be implemented 2x or 3x (redundancy)
- single elements are permissible for insensitive components

The components are defined in EN 50 020 Section 8.

15 Supply isolators

Supply isolators are used to achieve safe electrical isolation between those areas with an explosion hazard and areas that are free of any explosion hazard. For instance, they supply the operating voltage for 2-wire transmitters and transfer the electrically isolated measurement signal to the output. The power supplied to a 2-wire transmitter is limited.

When electrical isolation is used, there is no direct electrical contact between the circuits. The voltages that are applied are the determining factors for the insulation parameters. For safe electrical isolation, doubled or strengthened insulation must be used.

In a supply isolator the electrical isolation is between the auxiliary energy supply and the intrinsically safe circuit, between the supply and the output circuit, as well as between the input and output circuits.

Thanks to the electrical isolation that is provided, the supply isolator can be used with equipment for all zones.

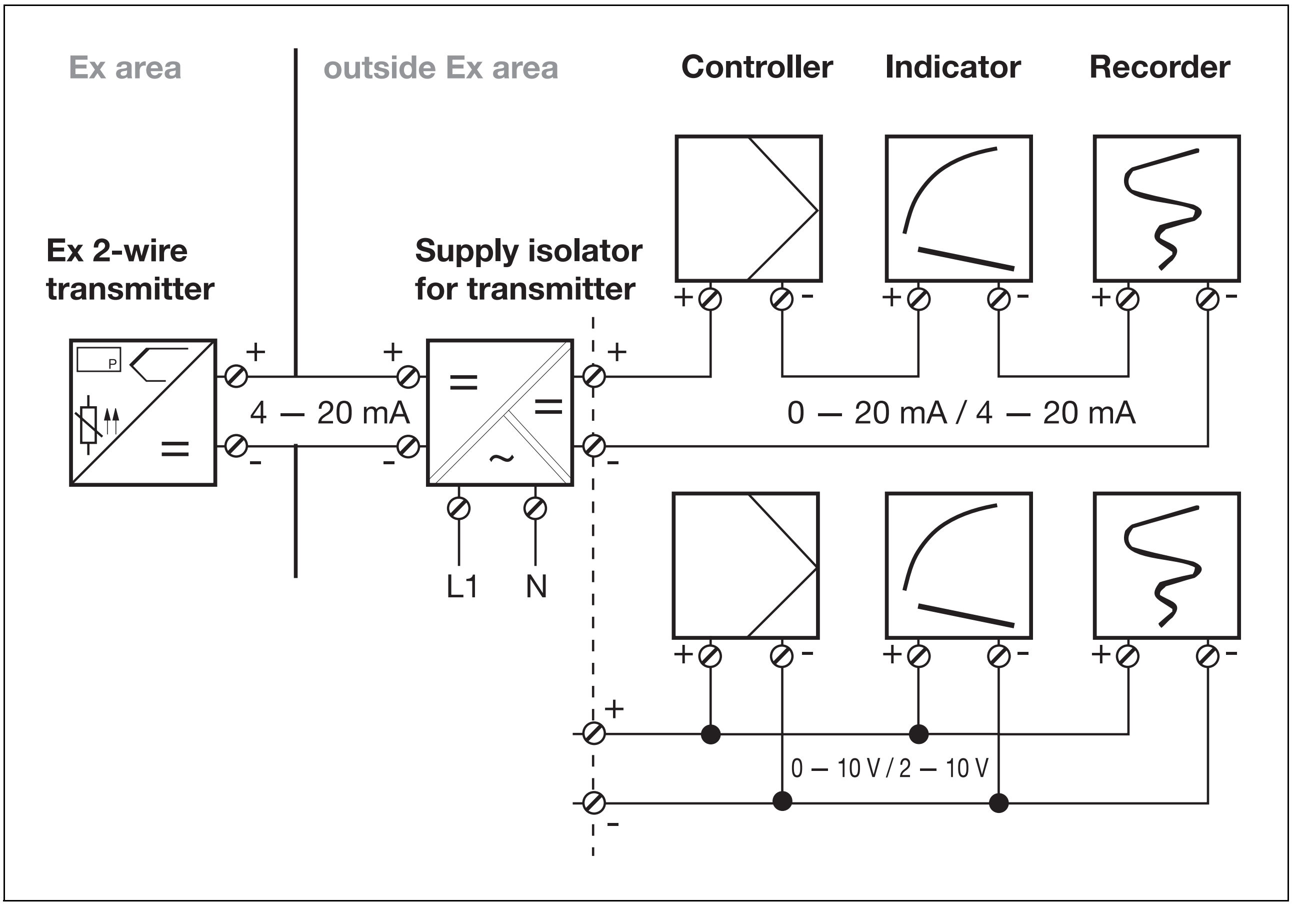


Fig. 21: Application of a supply isolator

In some cases it may be possible to use a safety barrier in accordance with EN 50 014 and EN 50 020 instead of a supply isolator.

16 Safety barriers

16.1 Brief description

Safety barriers are passive networks to separate intrinsically safe circuits from circuits that are not intrinsically safe, without using electrical isolation. By building them into the circuit, it becomes possible to use normal instrumentation and installation in the non-intrinsically-safe section of the circuitry, but no voltage greater than 250 V is permitted to appear. A disadvantage of safety barriers is that they have a relatively high electrical resistance. This must be taken into account for lead compensation.
Safety barriers are always wired into the circuit outside the Ex area.

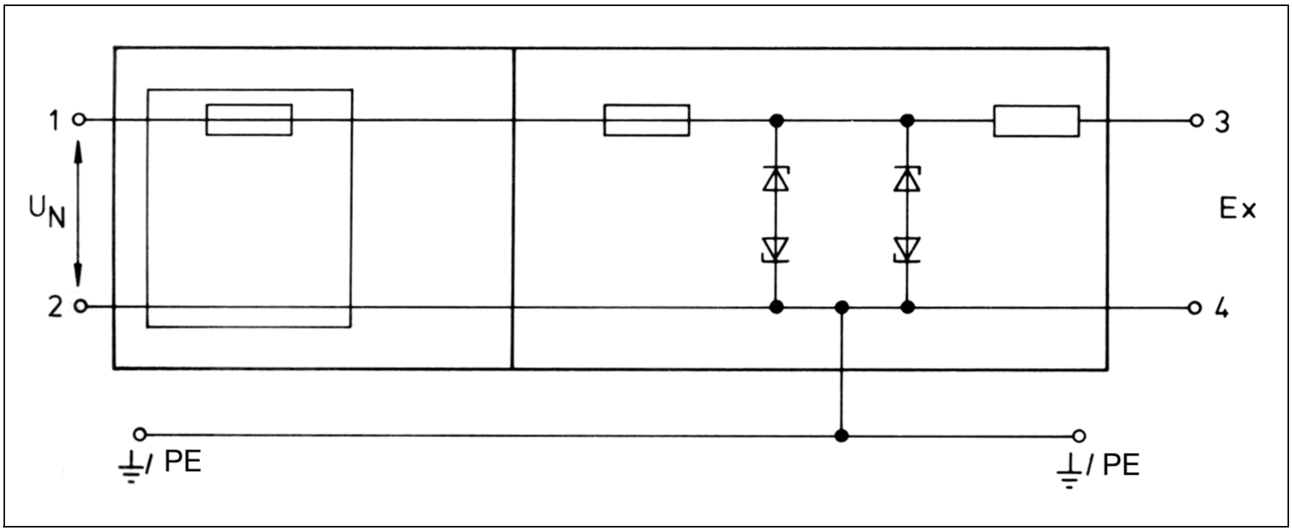


Fig. 22: Schematic diagram of a safety barrier

16.2 Operating principle of safety barriers

Safety barriers have the task of limiting the power that is fed into an intrinsically safe circuit, so that it cannot cause ignition by generating sparks or producing a hot surface.

Safety barriers consist of three important elements:

- Zener diodes for voltage limiting
- resistors for current limiting
- fuses, to protect the Zener diodes

As a rule, safety barriers do not have an electrical isolation between the input and output. This could lead to potential differences that would negate the intrinsic safety and make the explosion protection ineffective.

The safety barriers must be connected to a potential equilibration or earthing bus-bar. They are therefore designed so that a connection to the electrical earthing terminal PE (Protective Earth) is made directly through an electrically conductive snap-on mechanism to the mounting rail.

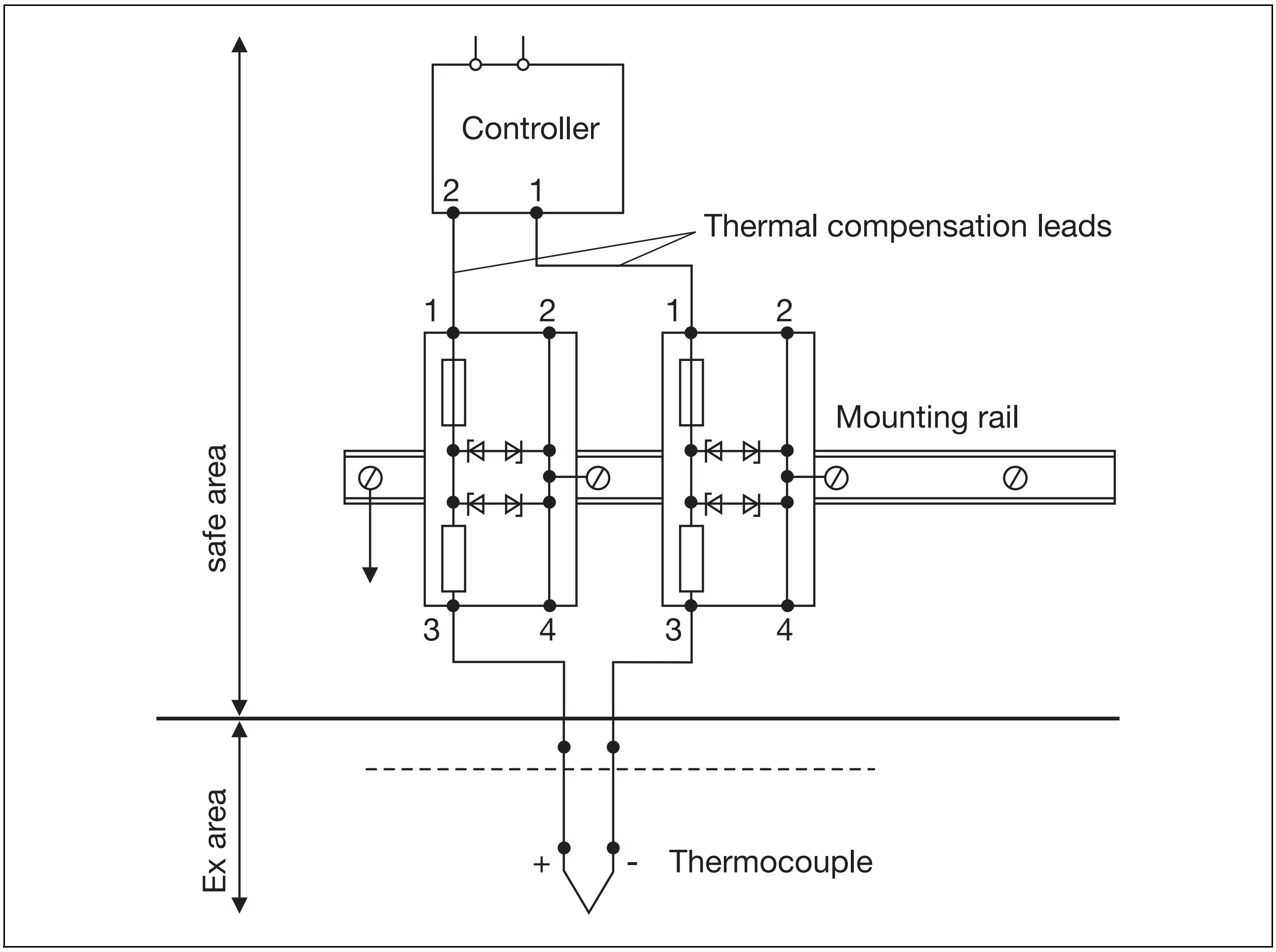


Fig. 23: Connecting a thermocouple via two safety barriers

16.3 Safety barriers with electrical isolation

Only safety barriers with electrical isolation are permitted for use in Ex Zone 0. In this case, a system earthing of the intrinsically safe equipment is permitted. There is no measurement error caused by different earth potentials. The intrinsically safe circuit and the evaluation equipment can have different potentials. Since a potential equilibration is not required, the installation expense is reduced.

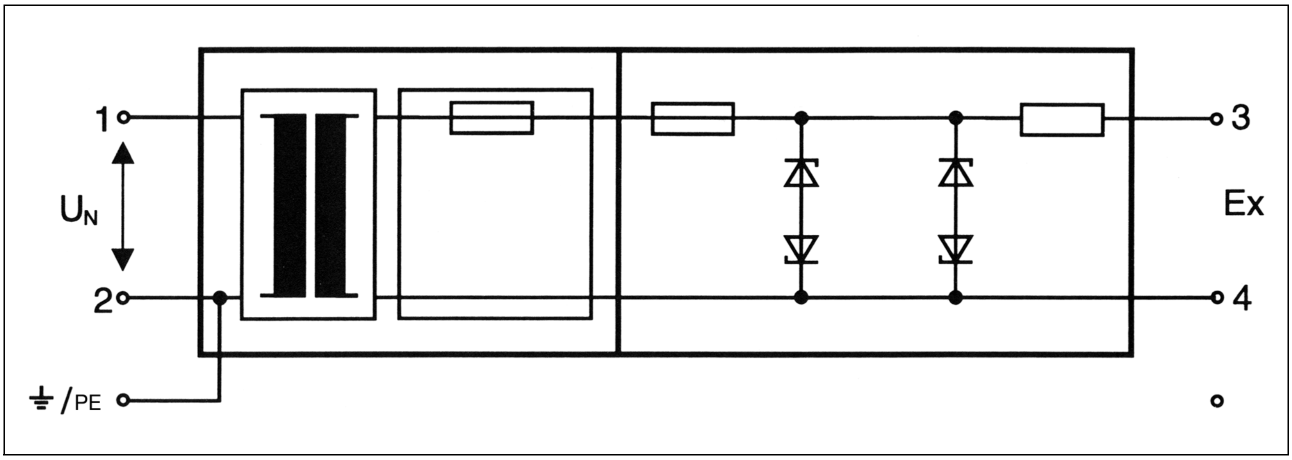


Fig. 24: Schematic diagram of a safety barrier with electrical isolation

17 Type examination of intrinsically safe equipment

Intrinsically safe equipment must undergo a type examination.
In the course of the associated spark test it must be proven that the electrical circuits are unable to cause ignition. The conditions that are laid down in the standards for categories and equipment groups must be observed. The spark test apparatus shown on the photograph is used for this test. For further details, see EN 50 020 Annex B.

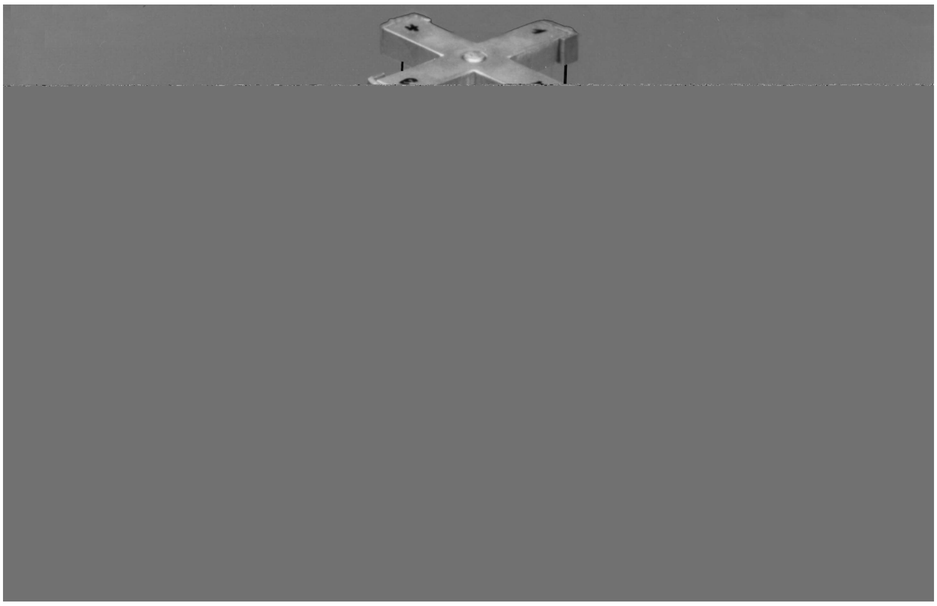


Fig. 25: Spark test apparatus

Various gas mixtures are used for testing, depending on the explosion group. As a rule, the test gases listed below must be used, mixed with air at the given volumetric ratios and at atmospheric pressure.

Group	Volumetric ratio	Gas
I	8.3 ±0.3%	Methane in air
IIA	5.25 ±0.25%	Propane in air
IIB	7.8 ±0.5%	Ethylene in air
IIC	21.0 ±2.0%	Hydrogen in air

Table 17: Explosion groups

This test is carried out with the circuit in normal, fault-free operation. Depending on the category of the equipment concerned, the test may also have to be conducted with one or two faults present. The maximum permissible values for external capacitance and inductance must be observed.

At least 400 rotations must be performed (200 in each direction) for DC circuits, and 1000 rotations for AC circuits. A safety factor of 1.5 (150 %) must also be taken into account. There must be no single instance of ignition during the test series.

Testing with the spark test apparatus can be left out if the design and the electrical parameters of the equipment are so precisely defined that its safety can be determined by using the ignition limit curves.

Intrinsically safe electrical equipment is not subjected to a test for surface temperature if the electrical values are so precisely defined that they can be used to calculate the surface temperature.

17.1 Ignition limit curves (reference curves)

Ignition limit curves are used as a basis for evaluating simple electrical circuits. These can be resistive, inductive or capacitive.
Limit conditions must be taken into account for all three cases (resistive, inductive and capacitive).
The total capacitance and total inductance in the circuit must be limited to such an extent that it is impossible for sparks to arise that could create ignition.
The ignition limit curves are shown in EN 50 020 Annex A.

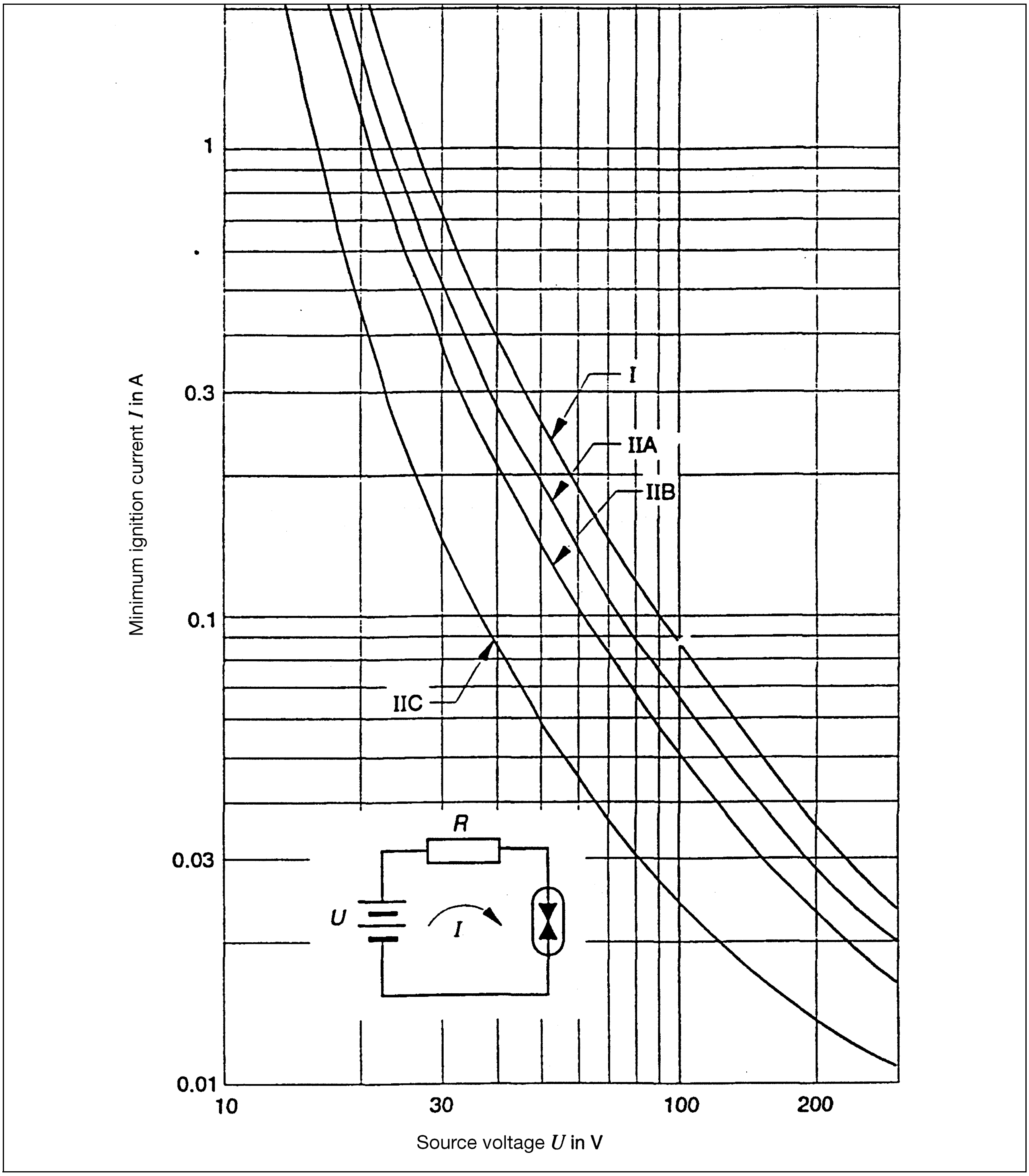


Fig. 26: Example of an ignition limit curve with a resistive circuit

However, they only apply to electrical equipment with a linear current/voltage output.
The manufacturer must state the limit values for voltage U, current I, power P, capacitance C and inductance L for every item of equipment or associated equipment that is to conform to intrinsic safety requirements. The value that is stated for voltage (U) is the unloaded voltage, and the current (I) value is the short-circuit current.

Gas group	IIC		IIB		IIA	
Safety factor	x1	x1.5	x1	x1.5	x1	x1.5
Voltage	Current					
V	mA	mA	mA	mA	mA	mA
:						
18.0	660	440	1660	1106	2238	1492
18.1	648	432	1630	1087	2188	1459
:						
24.5	248	166	618	412	841	561
24.6	246	164	612	408	830	554
:						
44.5	69.5	46.3	173	115	231	154
45.0	68.0	45.3	169	113	227	151

Table 27: Permissible short-circuit current, depending on the voltage and gas group (extract)

17.2 Proof of intrinsic safety

Aspect 1:
The simplest and most frequently occurring situation is the connecting together of an intrinsically safe circuit with associated equipment. The associated equipment is active, and the intrinsically safe equipment is passive. Both items of equipment have a linear characteristic.
A comparison of the maximum values must be carried out, in accordance with the European standard EN 60 079 Annex 12. The values can be taken either from the nameplates on the equipment, or the operating instructions, or the type examination certificate. The capacitance and inductance of the connecting leads must be included in the comparison. Particular attention must be paid to the self-heating in normal operation, and in the event of a fault.

Aspect 2:
If the intrinsically safe equipment and the associated equipment is active, then the voltages and currents must be added. The calculatory proof must be derived from the ignition limit curves and the fault evaluation according to EN 50 020.

Aspect 3:
If intrinsically safe equipment is connected that has a non-linear characteristic, then an appropriate calculation procedure must be applied.

Since the two last-mentioned examples are only rarely found in practice, a detailed study of the proof of intrinsic safety will not be made here. In such a case, the specific regulations must be followed.

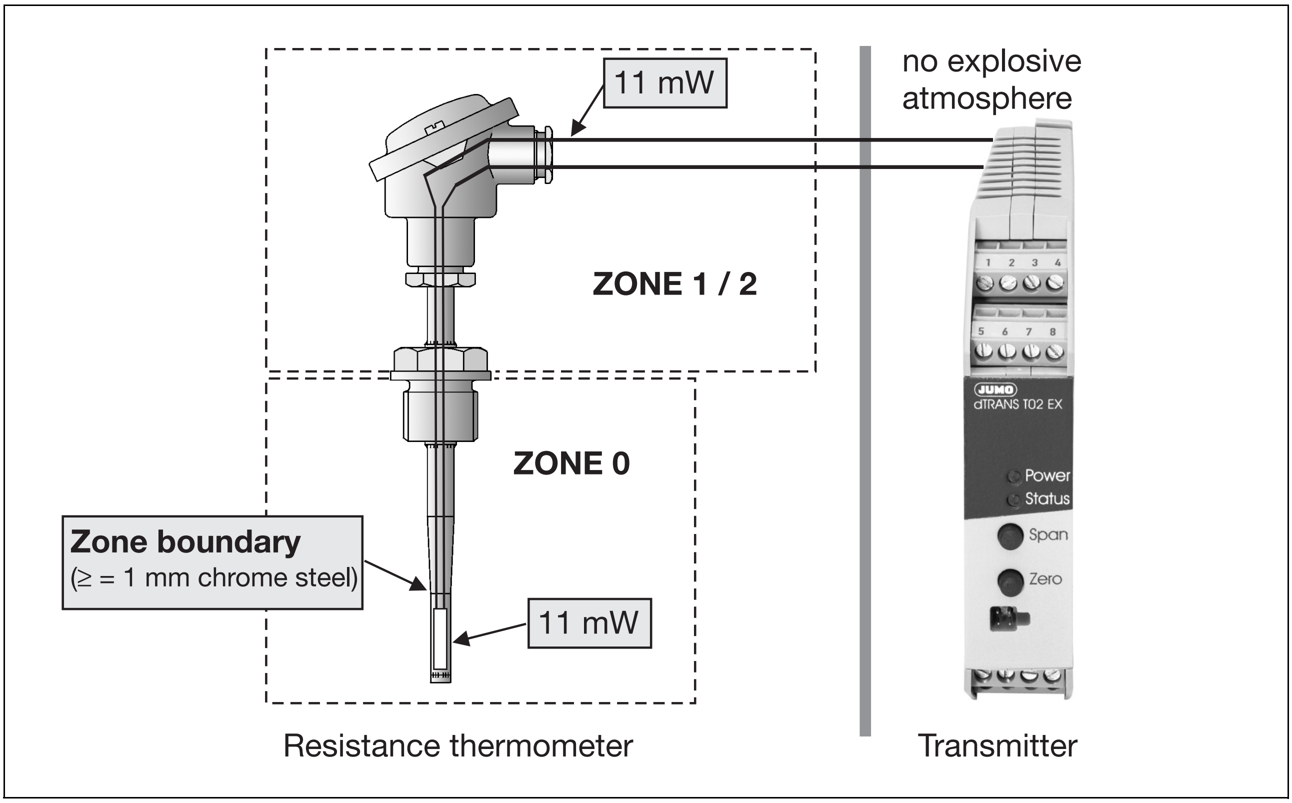


Fig. 28: Resistance thermometer with a transmitter as associated electrical equipment

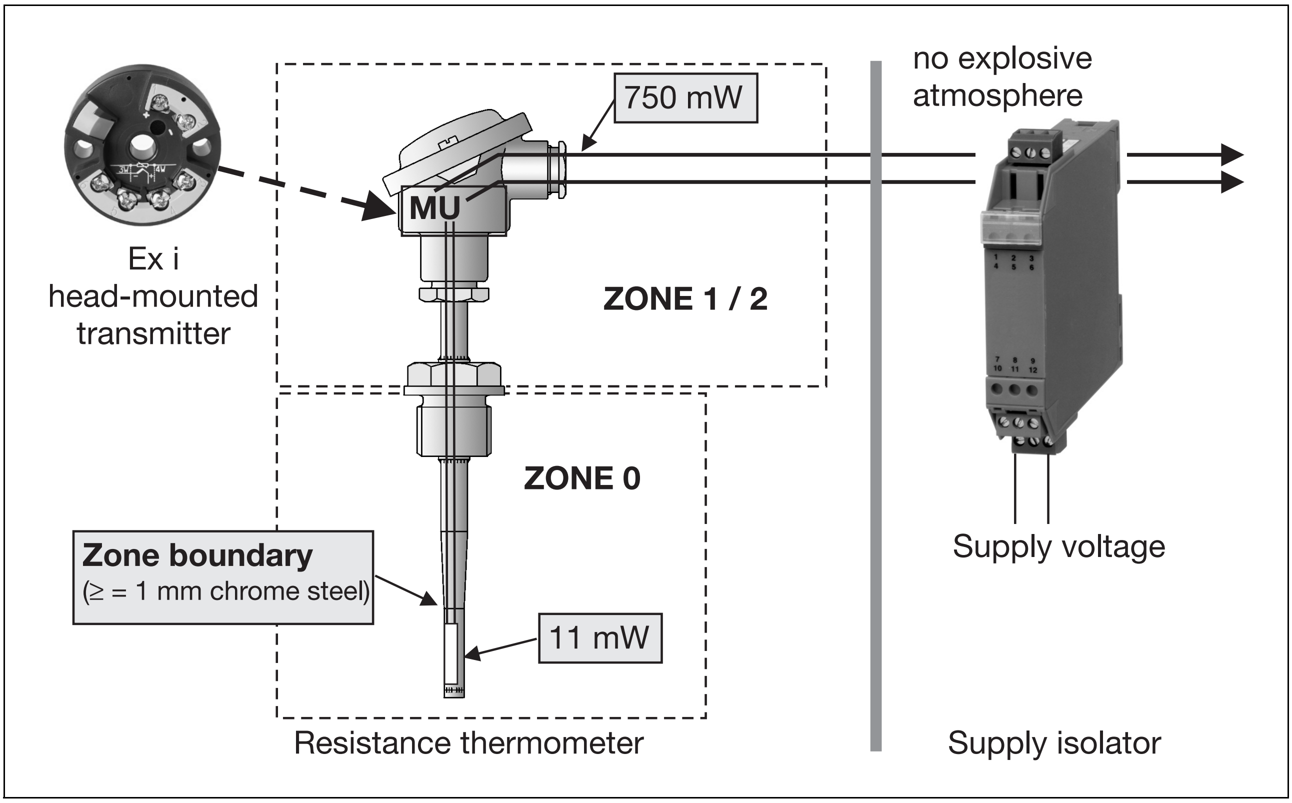


Fig. 29: Resistance thermometer with a head-mounted transmitter and a supply isolator as associated equipment

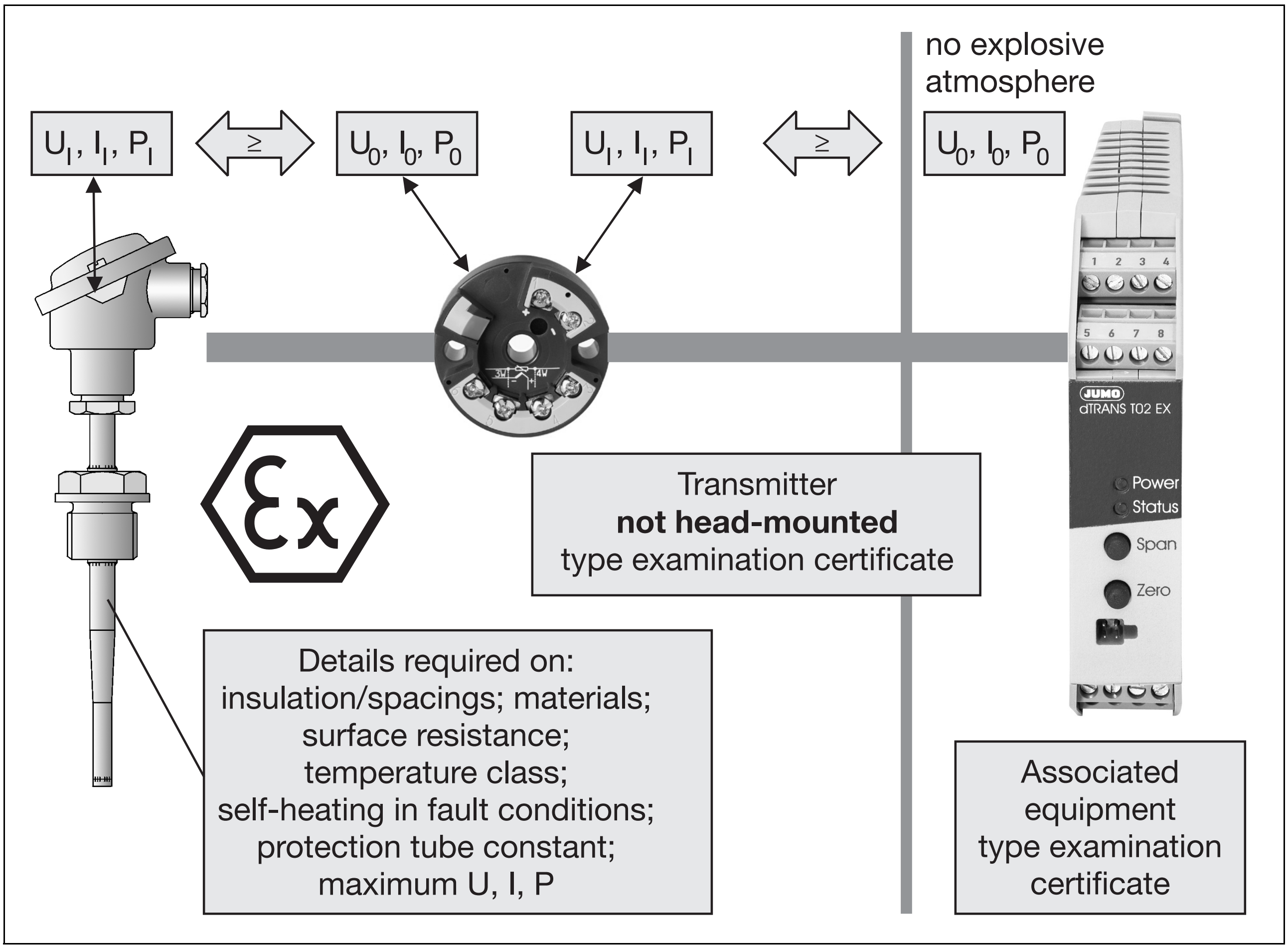


Fig. 30: Connecting intrinsically safe devices

19 JUMO resistance thermometers to ATEX

Resistance thermometers are components that require special attention when used in a potentially explosive atmosphere. In particular, great care must be taken when connecting resistance thermometers to other equipment. JUMO has therefore now gone over to having type examinations carried out in accordance with the EU Directive 94/9/EC (ATEX) for various resistance thermometer versions.

The assignment of a resistance thermometer to a temperature class depends on the self-heating behavior (protection tube constant SK) and the maximum power that can be delivered by the associated electronics in the event of a fault.

If a resistance thermometer is, for example, connected to a transmitter, then the measuring current provided by the transmitter produces an insignificant amount of self-heating in normal (fault-free) operation. However, in the event of a fault, a much higher current can flow through the resistance thermometer and cause greatly increased self-heating. If this self-heating is ignored, it could have catastrophic consequences. The limit for the temperature class could be exceeded. So series of measurements are made to establish a constant for the protection tube. This can be found in the data sheet for the thermometer.

The installer or operator of an installation in an area with an explosion hazard can make use of the protection tube constant to calculate the maximum permissible temperature at the tip of the thermometer when the thermometer is connected to other electrical equipment.

The relationship between the maximum measured temperature, the protection tube constant and the surface temperature is given by the equation

$$T_s = T_k - (P_o \cdot SK)$$

T_s maximum permissible temperature at the tip of the resistance thermometer (measurement temperature) in degrees Celsius [°C]

T_k maximum permissible temperature according to the temperature class in degrees Celsius [°C]

P_o power of the intrinsically safe circuit, in watts [W]

SK protection tube constant: external thermal resistance of the probe, in degrees Celsius per Watt [°C/W]

In this case, the effects of inductance and capacitance are insignificantly small. They are therefore not considered in the following examples.

Example 1:
The maximum power of an associated item of equipment (for instance, a transmitter) is limited to 0.5W in the event of a fault. A resistance thermometer is wired into the intrinsically safe circuit of the equipment. The protection tube constant is 66 °C/W (see Fig. 31).

The temperature class is assumed to be T4. This corresponds to a maximum permissible surface temperature of 135°C. According to the European Standard EN 50 014, the limits for temperature classes T6, T5, T4 and T3 must be reduced by 5°C (10°C for classes T1 and T2) during the thermal test.

This leads to the following calculation:

$$T_s = (135\ °C - 5\ °C) - (0.5\ W \times 66\ °C/W)$$
$$T_s = 97\ °C$$

The temperature of the medium being measured must not exceed 97 °C at the tip of the resistance thermometer probe. This ensures that the limits of temperature class T4 are not exceeded, even in the event of a fault.

Example 2:
A transmitter is mounted directly inside the terminal head of the resistance thermometer. The complete resistance thermometer and transmitter combination is used in a potentially explosive atmosphere (see Fig. 32). In this case, it is not enough just to calculate the maximum temperature of the medium, as in Example 1. It is also necessary to take into account the ambient temperature of the transmitter inside the terminal head. The specific data of the transmitter (see Table 28), the heat radiated from the medium being measured, the self-heating inside the terminal head and the ambient temperature of the terminal head must all be considered.

For JUMO products, for example, the following values will result:

JUMO products	P_o	I_o	U_o	P_i	I_i	U_i	T6	T5	T4
Supply isolator type 956056	547 mW	87.4 mA	25 V	-	-	-	-	-	-
Transmitter type 956555	11 mW	4.5 mA	9.6 V	750 mW	100 mA	30 V	55 °C	70 °C	85 °C
Index i = input; o = output									

Table 28: Device-specific data

From the data, it can seen that the maximum values for the supply isolator (P_o; I_o; U_o) are lower than the limits for the transmitter (P_i; I_i; U_i). A connection is therefore possible.

The JUMO resistance thermometer that is used is connected to the intrinsically safe circuit of the transmitter. The maximum output power for the transmitter is P_o = 11 mW.

Investigation: resistance thermometer
With an assumed protection tube constant SK = 66.14 °C/W and operating in temperature class T6, the maximum measurement temperature is

$$T_s = (85\ °C - 5\ °C) - (0.011\ W \times 66.14\ °C/W)$$
$$T_s = 79.3\ °C$$

Because of the very low power of the transmitter in the event of a fault, the temperature of the medium only has to be kept 5.7 °C lower than the limit value for temperature class T6 (85 °C).

Investigation: Terminal head with transmitter
In this example, the ambient temperature of the transmitter T_{MU} [°C] must not exceed 55 °C in temperature class T6 (see Table 28). This figure for temperature refers to the immediate surroundings of the transmitter. The installer or operator of the system must therefore take care that the self-heating of the transmitter, the heat radiated by the medium being measured, and the ambient temperature around the terminal head, do not raise the internal temperature of the terminal head above 55 °C.

The data sheet for the resistance thermometer provides helpful information in this case.

If the power dissipated by the transmitter is 750 mW, the expected increase in temperature T_V [°C] will amount to +10 °C.

A series of measurements is made under worst-case conditions, to establish the increase in internal temperature T_A [°C] of the terminal head that is caused by radiant heat. If a resistance thermometer is used with a tube neck (extension) length of 130mm, a medium temperature of 300°C will result in an increase of 18°C. It is possible to make a linear interpolation for other lengths and temperatures.

In our example, if one starts from the condition that the medium temperature can only be as high as 79.3°C, then a linear interpolation results in an increase of the internal temperature T_A [°C] of about +5°C as a result of heat radiation.

The permissible ambient temperature A_T [°C] (temperature around the terminal head) is therefore

$$A_T = T_{MU} - T_V - T_A$$

$$A_T = 55\ °C - 10\ °C - 5\ °C$$

$$A_T = 40\ °C$$

Note:
For equipment in Category 1 (for use in Zone 0), and thus for resistance thermometers as well, care must be taken that, under fault conditions, the surface temperature of the equipment does not exceed 80% of the ignition temperature [°C] of the flammable gases or liquids that are used (as per EN 1127)!

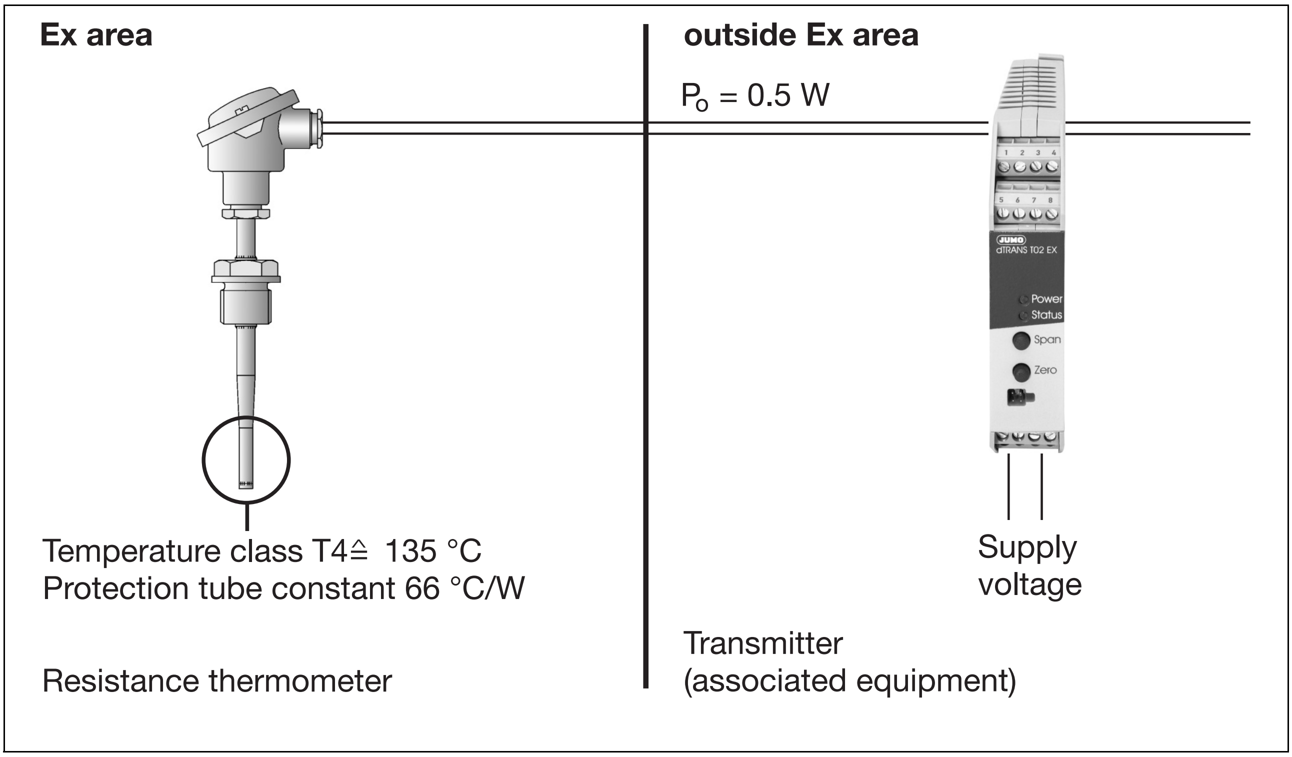


Fig. 31: Resistance thermometer with associated equipment

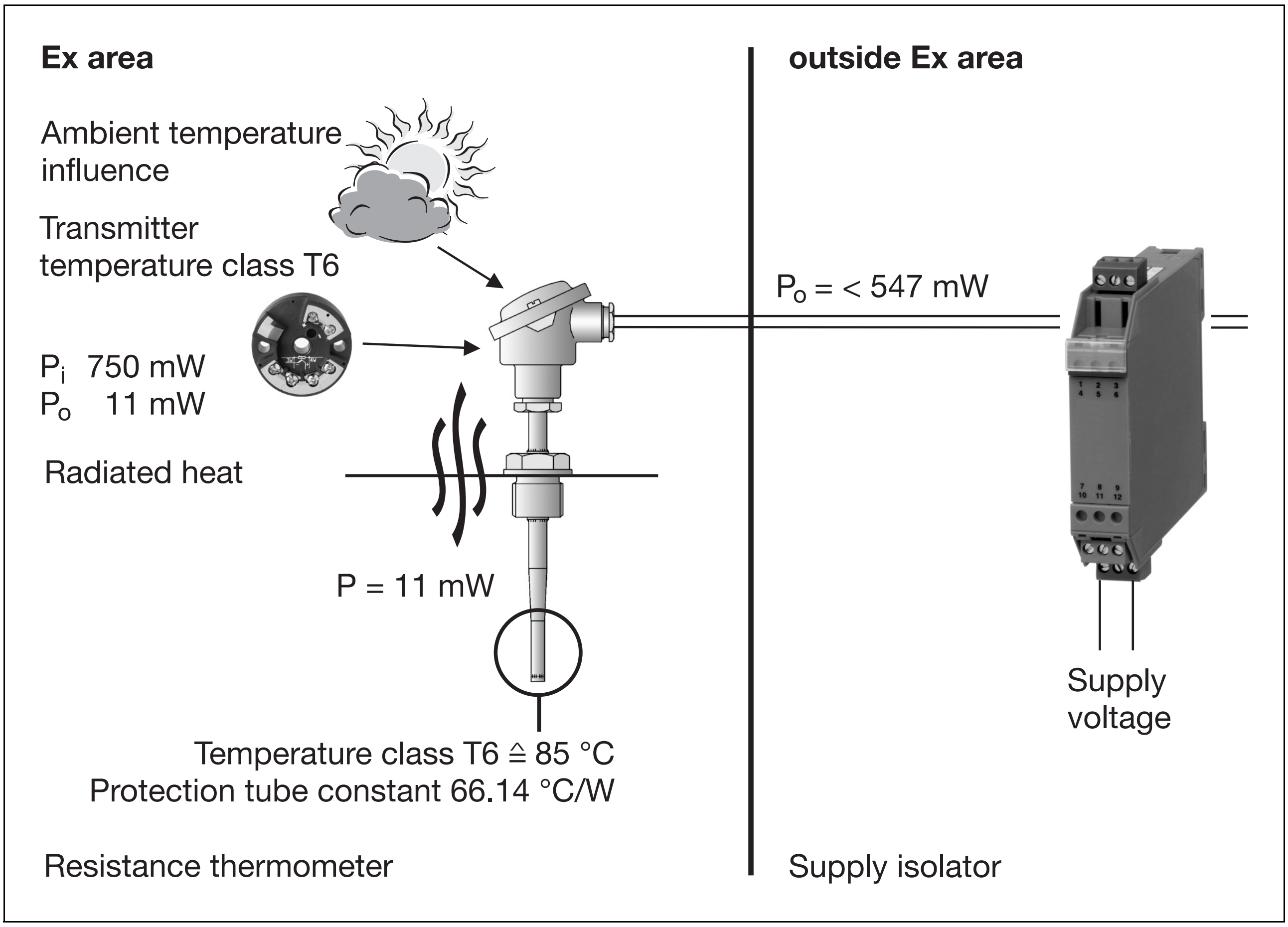


Fig. 32: Resistance thermometer with head-mounted transmitter

20 List of standards and sources

20.1 Standards

EN European standard	VDE standard	Title
EN 1127-1		Explosive atmospheres – Explosion prevention and protection – Basic concepts and methodology
EN 50 014	VDE 0170/0171 Part 1	Electrical apparatus for potentially explosive atmospheres General requirements
EN 50 015	VDE 0170/0171 Part 2	Electrical apparatus for potentially explosive atmospheres Oil immersion “o”
EN 50 016	VDE 0170/0171 Part 3	Electrical apparatus for potentially explosive atmospheres Pressurized apparatus “p”
EN 50 017	VDE 0170/0171 Part 4	Electrical apparatus for potentially explosive atmospheres Powder filling “q”
EN 50 018	VDE 0170/0171 Part 5	Electrical apparatus for potentially explosive atmospheres Flameproof enclosure “d”
EN 50 019	VDE 0170/0171 Part 6	Electrical apparatus for potentially explosive atmospheres Increased safety “e”
EN 50 020	VDE 0170/0171 Part 7	Electrical apparatus for potentially explosive atmospheres Intrinsic safety “i”
EN 50 021	VDE 0170/0171 Part 16	Electrical apparatus for potentially explosive atmospheres Non-sparking “n”
EN 50 028	VDE 0170/0171 Part 9	Electrical apparatus for potentially explosive atmospheres Encapsulation “m”
EN 50 039	VDE 0170/0171 Part 10	Electrical apparatus for potentially explosive atmospheres Intrinsically safe electrical systems “i”
EN 50 284	VDE 0170/0171 Part 12-1	Special requirements for construction, test and marking of electrical apparatus of equipment group II, category 1 G
EN 50 303	VDE 0170/0171 Part 12-2	Group I category M-1 equipment intended to remain functional in atmospheres endangered by firedamp and/or coal dust
EN 50 281-1-1	VDE 0170/0171 Part 15-1-1	Electrical apparatus for use in the presence of combustible dust Part 1-1 Electrical apparatus protected by enclosures – Construction and testing
EN 50 281-1-2	VDE 0165 Part 2	Electrical apparatus for use in the presence of combustible dust Part 1-2 Electrical apparatus protected by enclosures – Selection, installation and maintenance
EN 50 281-2-1	VDE 0170/0171 Part 15-2-1	Electrical apparatus for use in areas with combustible dust – Test methods
EN 61 241-2-2	VDE 0170/0171 Part 15-2-2	Electrical apparatus for use in areas with combustible dust Part 2 - Test methods Section 2 - Method for determining the electrical resistance of dust in layers
EN 60079-10	VDE 0165 Part 101	Electrical apparatus for explosive gas areas Part 10 – Classification of hazardous areas

20 List of standards and sources

EN European standard	VDE standard	Title
EN 60 079-14	VDE 0165 Part 1	Electrical apparatus for explosive gas areas Part 14 – Electrical installations in hazardous areas (other than mines)
EN 60 079-17	VDE 0165 Part 10	Electrical apparatus for explosive gas areas Part 17 – Inspection and maintenance of electrical installations in hazardous areas (other than mines)

20.2 Source list

DIN VDE 0164/2.91:
Errichtung elektrischer Anlagen in explosionsgefährdeten Bereichen

DIN VDE 0170/0171 Part 1 - 10
mit zugehörigen Änderungen gleichlautend mit EN 50 014 - 50 039

DIN VDE 0170/0171 Part 13:
Anforderungen für Betriebsmittel der Zone 10

EN 60 529:
IP enclosures; contact, foreign body and water protection ratings for electrical equipment

Memorandum (Ex) of: PTB Braunschweig, Gruppe 3.5:
Explosionsschutz elektrischer Betriebsmittel; Edition 04/95

Memorandum (Ex)i of: PTB Braunschweig, Gruppe 3.5; Edition 12/93

Directive 94/9/EC of the European Parliament and the Council of 23rd March 1994

Verordnung über elektrische Anlagen in explosionsgefährdeten Räumen (ElexV)

Richtlinie für die Vermeidung der Gefahren durch explosionsfähige Atmosphäre
mit Beispielsammlung - Explosionsschutzrichtlinie (Rx-RL)

Technical publication by L. Börner:
Explosionsschutz nach Europa-Norm - Rechtsunsicherheit vermeiden; Hütig-Verlag

JUMO technical publication by J. Goldmann:
Theorie und Anwendung von (Ex)i-Zener-Barrieren

Technical publication by Dr. N. Müller:
Lagerung von brennbaren Flüssigkeiten - Vorschriften geändert; Chemie Umwelt Technik

Technical publication by Dipl.-Ing. R. Thater:
Beliebige Oberflächentemperatur

Technical publication by Bürkert GmbH:
Explosionsschutz nach Europanorm; Chemie-Technik

Technical publication by Dipl.-Ing. W. Bansemir and Dipl.-Ing. W. D. Dose:
Grundlagen für den Ex-Schutz in der Praxis; Chemie-Technik

Technical publication by Dipl.-Ing. M. Winkelmann:
Eigensichere MSR-Anlagen

20 List of standards and sources

Technical publication by Dipl.-Ing. Pulewka:
Zündende Ideen; Chemie-Technik

Technical publication by A. Schischek:
Die richtige Lösung der MSR-Technik in der Ex-Zone; Chemie-Technik

Prof. Dr.-Ing. H. Wehinger:
Explosionsschutz elektrischer Anlagen; expert-Verlag

EN/VDE-Normen; Beuth-Verlag, Berlin

Figs. 16 – 18
Ex Zones
Grundsätze des Explosionsschutzes mit Beispielsammlung;
Suva - Schweizerische Unfallversicherungsanstalt

Figs. 2 and 25
Fachstelle für Sicherheit elektrischer Betriebsmittel - BVS

Index

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