Basics of Explosion Protection

Introduction to Explosion Protection
for Electrical Apparatus and Installations

STAHL

R. STAHL SCHALTGERÄTE GMBH

A company of the
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PRODUCT RANGE

Switchgear	Lighting	Instrumentation
Installation equipment	Fluorescent light fittings	Safety barrier modules
Control and monitoring equipment	Emergency fluorescent light fittings	I.S. Isolators
Terminal boxes and control stations	Light fittings in sheet steel	Remote I/O
Position switches	Pendant light fittings	Operating and monitoring systems
Load and motor switchgear	Bulk head light fittings	Instrumentation systems
Switching and distribution systems with EEx modules	Floodlights	
Switching and distribution systems with flameproof enclosures	Portable lamps	
Control equipment in pressurized enclosures	Portable searchlights	
Signaling and monitoring equipment	Tank inspection lights	
Measurement and control equipment	Emergency light power supply units	
Equipment for conduit installation		

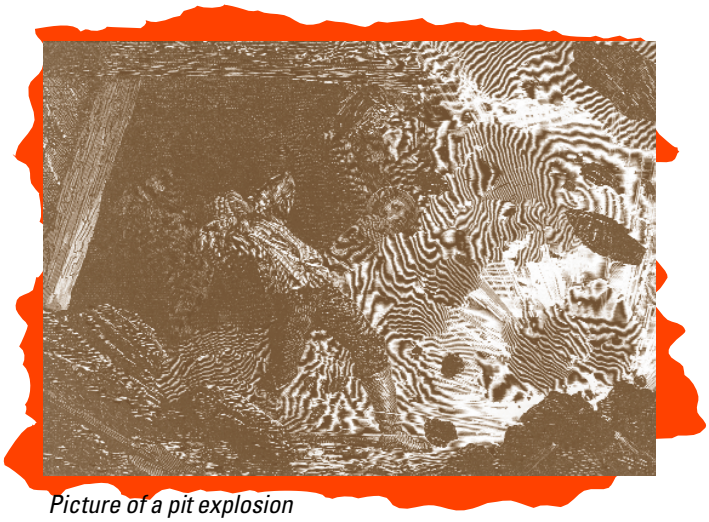
Introduction

It is a fact that gases, vapours and mists escape during the production, processing, transportation and storage of flammable materials in the chemical and petrochemical industries, as well as in the production of mineral oil and natural gas, in mining and in many other sectors. During many processes also flammable dusts are created. These flammable gases, vapours, mists and dusts, form an explosive atmosphere with the oxygen of the air. In the case that this atmosphere is ignited, explosions take place which can result in severe harm to human life and property

To avoid the danger of explosions, protective regulations in form of laws, specifications and standards have been developed in most countries and are aimed at ensuring that a high level of safety is observed. Due to the growing international economic link, extensive progress has been made in harmonizing the regulations for the explosion protection. The conditions for a complete harmonization have been created in the European Union by the 9/94 EC Directive. However, world-wide there is still much to be done in this area.

The aim of this brochure is to provide both experts and interested laymen with an overview in the field of explosion protection; in conjunction with electrical apparatus and installations, it does not replace the study of the relevant statutory regulations and applicable standards.

In mining, miners underground have always lived under the threat of firedamp explosions. Herein lie the origins of explosion protection, which has been consistently developed in industrialized countries and now provides a high level of safety.



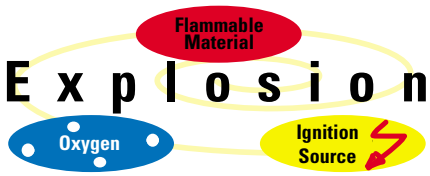
Picture of a pit explosion

Contents

1. The basic physic Principles and Definition of Explosion Protection

An explosion is the sudden chemical reaction of a flammable material with oxygen with the simultaneous release of high energy. Flammable materials may be present in the form of gases, vapours, mists or dusts. In order for a fire or explosion to occur three conditions must exist:

1. Flammable material (in ignitable quantities)
2. Oxygen (in the air)
3. Ignition source

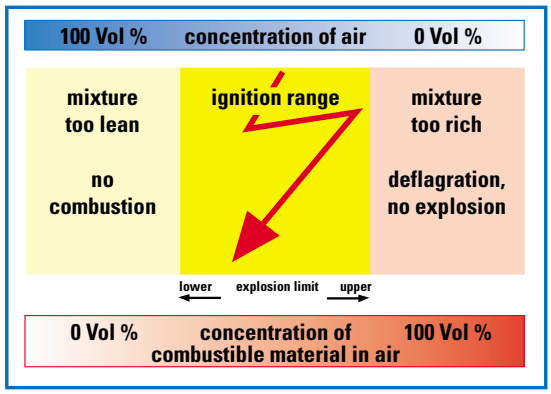


Certain characteristic properties of these materials are required for safety considerations. The flash point of a flammable liquid is the minimum temperature at which a liquid gives off vapour in sufficient concentration to form an ignitable mixture with air near the surface of the liquid (at normal air pressure). If the flash point of a flammable liquid is far above the maximum temperatures which arise, an explosive atmosphere may not be formed. The flash point of a mixture of various liquids may be lower than that of the individual components.

Flammable liquids are classified into four danger classes in the German Technical Regulations for Flammable Liquids (TRbF):

Danger class	Flash point
AI	< 21°C
AII	21 to 55°C
AIII	> 55 to 100°C
B	< 21°C, soluble in water at 15°C

For an explosive atmosphere to form, the flammable material must be present in a certain concentration.



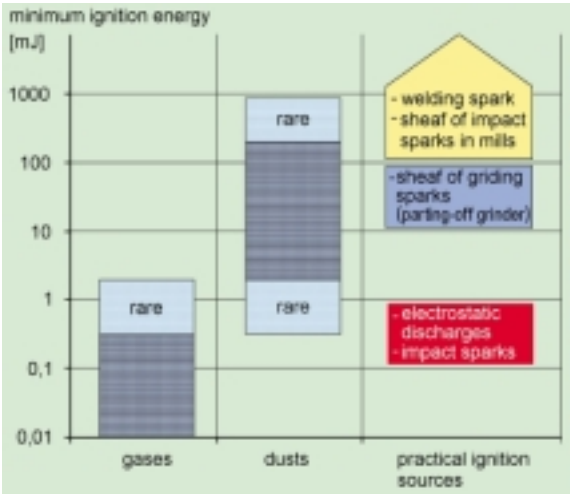
If the concentration is too low (lean mixture) or too high (rich mixture), no explosion occurs, rather there is just a slow combustion reaction or none at all. It is only in the range between the lower and upper explosion limit that the mixture reacts explosively when ignited. The explosion limits depend on the ambient pressure and the proportion of oxygen in the air.

Substance designation	Lower explosion limit [Vol. %]	Upper explosion limit [Vol.%]
Acetylene	2.3	78.0 (self-decomposing)
Ethylene	2.3	32.4
Gasoline	~ 0.6	~ 8
Benzol	1.2	8
Natural gas	4.0 (7.0)	13.0 (17.0)
Heating oil/diesel	~ 0.6	~ 6.5
Methane	4.4	16.5
Propane	1.7	10.9
Carbon disulphide	0.6	60.0
Town gas	4.0 (6.0)	30.0 (40.0)
Hydrogen	4.0	77.0

Explosion Limits of selected Gases and Vapours
Extract from the table "Safety characteristics of flammable gases and vapours" by K. Nabert and G. Schön - (6th addendum)

The terms used here are deflagration, explosion or detonation, depending on the speed of combustion.
An atmosphere is described as dangerous or explosive if there is danger to human life or to property. An explosive atmosphere of even just a few litres can be dangerous in an enclosed space.

Source of Ignition
In order for an explosive atmosphere to ignite, a certain amount of energy is needed. The minimum ignition energy is the smallest possible amount of energy which is converted during the discharge of a capacitor and is just enough to ignite the most ignitable mixture. The minimum ignition energy is around 10^{-5}J for hydrogen and a few joules for certain dusts.



Comparison between the minimum ignition energy of gases, dusts and practical sources of ignition.

Ignition can be caused by various sources:

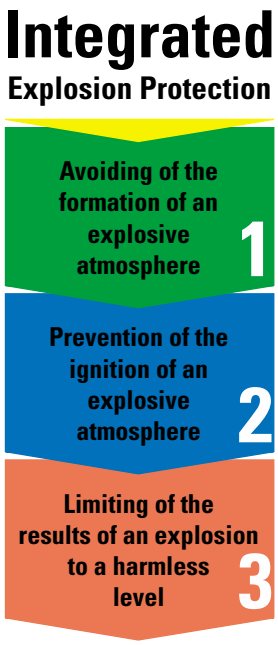
- hot surfaces
- electrical arcs and sparks
- electrostatic discharge
- atmospheric discharge (lightning)
- mechanical friction or impact sparks
- electromagnetic radiation
- ultrasonics
- adiabatic compression (shock waves)
- ionizing radiation
- optical radiation
- chemical reactions
- open flames

Primary Explosion Protection

The term primary explosion protection refers to all precautions which prevent a dangerous, explosive atmosphere from being created.
This can be achieved by:

- avoiding flammable substances (replacement technologies)
- deactivation (addition of nitrogen, carbon dioxide etc.)
- limitation of the concentration
- natural or artificial ventilation

The principle of integrated explosion protection requires explosion protection measures to be taken in a certain sequence.



Secondary Explosion Protection

If the danger of explosions cannot be completely or only partly avoided by primary explosion protection measures, then measures must be taken which prevent the ignition of an explosive atmosphere. The hazardous locations are therefore devided into zones, according to the probability of an explosive atmosphere being created (see Section 3.1). In the USA and other countries, hazardous locations are classified into Classes and Divisions (see Section 5). For areas classified in this way, requirements must be met concerning the apparatus which are approved to be used in these locations. In addition it is stipulated how to prove that these minimum requirements have been met (see section 2.2.3 and 5.6).

Polyester Resin Control Station 8146

2. Statutory Regulations and Standards

2.1 International Standards

The IEC (International Electrotechnical Commission) is responsible for international standardization in the field of electrical technology. IEC publications which deal with explosion protection for electrical apparatus and installations, are developed by the Technical Committee TC31. IEC publications have the status of recommendations which are used for orientation purposes for national and regional standards (see Appendix 6.1).
The IEC has introduced a procedure - the so called IEC-Ex Scheme - intended to become a globally recognized test and certification procedure in the field of explosion protected electrical apparatus. Many technical and legal hurdles still have to be overcome before this procedure can operate world-wide.

2.2 European Directives and Standards

2.2.1 Introduction

Already in 1976 the Council of the European Community established the prerequisite for unrestricted trade of explosion protected electrical equipment within the European Union by ratifying the "Directive on the harmonization of the laws of the member states concerning electrical equipment for use in potentially explosive atmospheres (76/117/EEC)".
This directive has since then been supplemented by further directives.
Complete harmonization in this area was achieved in 1994 with the new Directive 94/9/EC. Of course, in addition to a uniform statutory regulation, uniform standards are required as well. CENELEC is the European Committee for Electrotechnical Standardization in which the countries of the European Union and the West European EFTA states cooperate.
European standards (EN) are published in three official versions (French, English and German). The members of CENELEC are obliged to adopt the European Standards unchanged as national standards.

The European Standards series EN 50 014 and following which deal with electrical explosion protection, have been developed by the Technical Committee CENELEC TC31 and adopted in the EU states as identical national standards (see table below).

It is determined that the member states of the European Union may not forbid the free trade of electrical apparatus, if it complies with these standards and has a Certificate of Conformity from a recognized EC testing authority.

The European directives and the uniform standards in the field of electrical explosion protection have proved to be very worthwhile in practice.

2.2.2 EC Directive 94/9/EC (ATEX 100a)

The EC Directive 94/9/EC was issued in 1994 to further standardize explosion protection and make corresponding adjustments in line with a new directive concept. It specifies the requirements for explosion protected equipment and protective systems by prescribing essential health and safety requirements. It guarantees the free trade within the European Community, as agreed in Article 100a of the Treaty established between the European Community member states. This is also where the term ATEX 100a, generally used among the experts , comes from.

The directive applies to all industrial potentially explosive areas including mining and also covers dust explosion protection. The scope covers all electrical and mechanical equipment and protective systems. In addition to the basic health and safety requirements, the classification of the equipment and protective systems according to categories has also been re-organized, as well as the certification and marking of these.

Constructional Requirements for Explosion Protected Electrical Apparatus

	CENELEC	Germany	France	Great Britain
General requirements	EN 50 014	DIN EN 50 014 VDE 0170/0171 T. 1	NF EN 50 014	BS EN 50 014
Type of protection "o"	EN 50 015	DIN EN 50 015 VDE 0170/0171 T. 2	NF EN 50 015	BS EN 50 015
Type of protection "p"	EN 50 016	DIN EN 50 016 VDE 0170/0171 T.3	NF EN 50 016	BS EN 50 016
Type of protection "q"	EN 50 017	DIN EN 50 017 VDE 0170/0171 T.4	NF EN 50 017	BS EN 50 017
Type of protection "d"	EN 50 018	DIN EN 50 018 VDE 0170/0171 T.5	NF EN 50 018	BS EN 50 018
Type of protection "e"	EN 50 019	DIN EN 50 019 VDE 0170/0171 T.6	NF EN 50 019	BS EN 50 019
Type of protection "i"	EN 50 020	DIN EN 50 020 VDE 0170/0171 T.7	NF EN 50 020	BS EN 50 020
Type of protection "n"	prEN 50 021	pr DIN EN 50 021 pr VDE 0170/0171 T.16	pr C23-521	BS 6941
Type of protection "m"	EN 50 028	DIN VDE 0170/0171 T.9	NF EN 50 028	BS 5501:Part 8

Definitions

• "Electrical installations" are individual or interconnected items of apparatus for the generation, conversion, storage, transmission, distribution, measurement, regulation, and consumption of electrical energy.

• "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.

• "Protective systems" is the definition for 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 separately placed on the market for use as autonomous systems. The components of the above defined equipment are not to be considered "protective systems".

•"Components" means any item essential for the safe functioning of equipment and protective systems but with no autonomous function

• An "explosive atmosphere" is a mixture with air, under atmospheric condition, of flammable substances in the form of gases, vapours, mists, or dusts in which, after ignition has occured, combustion spreads to the entire unburned mixture.

• A "potentially explosive atmosphere" is an atmosphere which could become explosive due to local and operational conditions.

Scope

The directive applies to equipment and protective systems for use in potentially explosive atmospheres. Safety devices intended for use outside potentially explosive atmospheres but required for or contributing to the safe functioning of equipment with respect to explosion are also covered by the scope of this Directive. The Directive ATEX 100a doesn't include a reference to mandatory standards, whereas specifies the essential health and safety requirements to be maintained and which are mandatory for the design and construction. The protection against other hazards (e.g. electric shock) which could be caused by this equipment, is required as well.

2.2.3 Certification and Marking

In potentially explosive atmospheres only approved and marked equipment is allowed to be used. For the placing on market of explosion protected equipment two directives apply in parallel.

EC Directive	**79/196/EEC**	**94/9/EC**
Validity	until 30.06.2003	since 01.03.1996
Range of validity for equipment in hazardous areas	- Electrical equipment - Gases and vapours - not for mining	- All equipment and protective systems - Gases and vapours and dusts - including mining
QM system of manufacturer	no requirements	"QM certificate" from a designated authority
Certificate of conformity	Certificate of conformity or inspection certificate from a resting authority	Manufacturer's declaration of on the basis of type conformity examination
Marking is specified by the Directive and the applicable standards		
Name or mark of manufacturer	STAHL	STAHL
Type designation, (e.g.)	6000/562-....	6000/562-....
Address	—	D-Künzelsau
CE mark, number of testing authority, (e.g. PTB)	—	CE 0102
Testing authority, Number of certificate, (e.g.)	PTB No. Ex- 91.C.1045 **1)**	PTB 97 ATEX 2031 **1)**
Mark according to EC Directive (free trade of goods)	Ex **2)**	Ex **2)**
Group and equipment category: Mining (I) Others (II)	I or II	Group I: M 1 or M 2 Group II: 1 G/D, 2 G/D, 3 G/D
Marking in accordance with EN	EEx / Ex	EEx / Ex
Types of protection, (e.g.)	d, e, q, ... ib or [ib] **3)**	d, e, q, ... ib or [ib] **3)**
Subdivision for Group II (only for d and i)	A or B or C	A or B or C
Temperature class for II	T1 - T6	T1 - T6
Electrical ratings	V, A, W, Hz	V, A, W, Hz
Ambient temperature, if other than -20 °C ... +40 °C, (e.g.)	Ta ≤ 50 °c	Ta ≤50 °c

1) With an ... X if reference special conditions for use etc.
With a ... U for Ex components

2) new: always present, old: not on Ex components

3) Intrinsically safe apparatus: ib / associated apparatus: [ib]

Manufacturer's EC Declaration of Conformity (94/9/EC)
The CE conformity marking and the written declaration of conformity confirm that the product complies with all requirements and assessment procedures specified in the EC Directives.
The certificates from notified bodies are recognized throughout the European Community, moreover many testing authorities have concluded bilateral agreements with other national testing authorities outside the EC regulating the acceptance of test results (Appendix Overview of Testing Organizations).

Marking
In addition to the usual data such as the name of the manufacturer, type, serial number and electrical ratings, any data relating to explosion protection must be contained in the marking (see table above).

The CE marking of the equipment confirms that it is designed and manufactured in compliance with all applicable EC Directives. For example, an explosion protected luminaire marked with the CE conformity mark must comply with both the "Explosion Protection Code of Practice" as well as the "EMC - Directive".

2.3 The Statutory Regulations in Germany
The Directive 94/9/EC (ATEX 100a) required the last modification for the time being to the national regulations. It was adopted completely into German law on 12 December 1996 when the 11th Regulation on the Equipment Safety Law became effective.

The requirements concerning equipment used in hazardous locations are stipulated in the Regulation on Placing on the Market of Equipment and Protective Systems - Regulation concening Electrical Installations in Explosive Atmospheres (ExVO)".
The installation and operation of electrical systems in hazardous locations is governed by the "Regulation concerning Electrical Installations in Explosive Atmospheres (ElexV)", which includes a reference to the ExVO in respect of the requirements concerning the equipment.

These new regulations will replace all previous relevant regulations with effect from 1.7.2003.
During the transition period, equipment can be certified for use in explosive atmospheres in accordance with the previous regulation as well as the new Ex-Directive 94/9/EC.
A mixing of both regulations is possible, provided the basic health and safety requirements of the Directive have been met.

3. Technical Principles

3.1 Zone Classification

Hazardous locations are classified into zones to facilitate the selection of appropriate electrical apparatus as well as the design of suitable electrical installations. Information and specifications for the classification into zones are included in IEC 60 079-10 and in national standards.
Furthermore, a European Directive (ATEX 118a), which deals with the installation and operation of electrical systems in hazardous locations and governs the zone classification within the EC, is currently being prepared.
The following table contains an overview of the zones and allocation of equipment (equipment category according to 94/9/EC) for the relevant zones.

Gases, Vapours, Mists	Dusts	Definition (94/9/EC) explosive atmosphere is present:
Zone 0 → Category 1 G	Zone 20 → Category 1 D	continiously or long-term or frequently
Zone 1 → Category 2 G	Zone 21 → Category 2 D	occasionally
Zone 2 → Category 3 G	Zone 22 → Category 3 D	infrequently or short period
G = gases, D = dusts		

If there are any doubts with the zone classification, the scope of the protective measures in the entire hazardous location should be based on the highest possible degree of likelihood of the occurance of dangerous explosive atmosphere. In such cases use of specialists is recommended.

In Zones 0 and 1, only electrical apparatus with a Certificate of Conformity or EC Type Examination Certificate may be used, however in Zone 0 only equipment which has been expressly approved for this purpose. In Zone 2, electrical apparatus which meet the basic health and safety requirements of the Directive 94/9/EC and which has a Manufacturer's Declaration of Conformity can be used. Of course, equipment which has been certified for use in Zones 0 and 1 may also be used in Zone 2.

3.2 Explosion Groups and Temperature Classes

It would be uneconomical and sometimes not even possible to design all explosion protected electrical apparatus in such way that it always meets the maximum safety requirements, regardless of the use in each case. For this reason, the equipment is classified into groups and temperature classes in accordance with the properties of the explosive atmosphere for which it is intended.

First of all a differentiation is made between two groups of equipment:

Group I: Electrical apparatus for mining.

Group II: Electrical apparatus for all remaining potentially explosive atmospheres.

In the case of electrical apparatus in Group I (mining), it is assumed that the only flammable gas to occur is methane, but in combination with coal dust. Other flammable gases which can also occur in these areas must be further classified as shown in Group II.

Electrical apparatus in Group II is further classified into explosion groups and temperature classes.

Explosion Groups

The ignitability and explosion characteristics of an explosive mixture are properties typical of the material. The gases and vapours are classified into explosion groups. Classification criteria are the "Maximum Experimental Safe Gap (MESG)" and the "Minimum Ignition Current (MIC)". The MESG and MIC are determined for the various gases and vapours according to a stipulated testing arrangement. The maximum experimental safe gap is the gap width of a vessel with an adjustable gap of 25 mm path length at which an internal ignition of an explosive mixture is not propagated to the exterior (IEC 60 079-1A). The minimum ignition current relates to the minimum ignition current for laboratory methane (IEC 60 079-3).
An overview of the maximum experimental safe gaps and minimum ignition currents for the various explosion groups is shown in the following table:

Explosion groups	Maximum experimental safe gap	Minimum ignition current ratio rel. to methane
II A	> 0.9 mm	> 0.8
II B	0.5 mm to 0.9 mm	0.45 to 0.8
II C	< 0.5 mm	< 0.45

The dangerousness of the gases increases from explosion group IIA to IIC. The requirements for the electrical apparatus increase accordingly to these explosion groups. For this reason, the marking of the electrical apparatus must show for which explosion group it is designed. Electrical apparatus approved for IIC may also be used for all other explosion groups.

Temperature Classes

The ignition temperature of a flammable gas or liquid is the lowest temperature of a heated surface at which the gas/air or vapour/air mixture ignites. It is ascertained using precisely defined test equipment (IEC 60 079-4) and represents virtually the lowest temperature at which a hot surface can ignite a respective explosive atmosphere. Flammable gases and vapours may be classified into temperature classes using the ignition temperature.

The maximum surface temperature of electrical apparatus shall always be lower than the ignition temperature of the gas/air or vapour/air mixture in which it is used. Of course, equipment classified in a higher temperature class (eg T5) may also be used for application in which a lower temperature class is required (eg T2 or T3). In North America there is a system incorporating further classification according to temperature subclasses.

3.3 Types of Protection

Only explosion protected equipment may be used in areas in which a dangerous, explosive atmosphere may still be expected despite the implementation of primary explosion protection measures.

Electrical, explosion protected equipment can have various types of protection according to the construction regulations of the series of standards EN 50 014 following (DIN VDE 0170/0171 Part 1 - following). The type of protection used by the manufacturer for apparatus essentially depends on the type and function of the apparatus. From a safety point of view, all standardized types of protection should be seen as being equal, but it should be noted here that the type of protection "n" can only be used in Zone 2.

The table on page 13 shows an overview of the standardized types of protection and describes the basic principle as well as the usual applications.

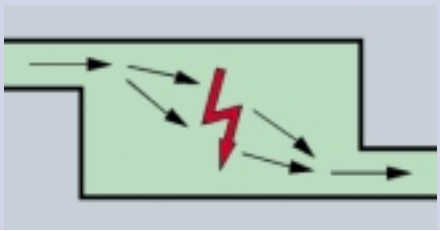
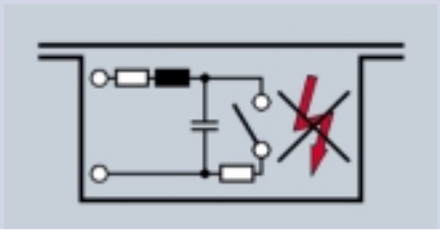
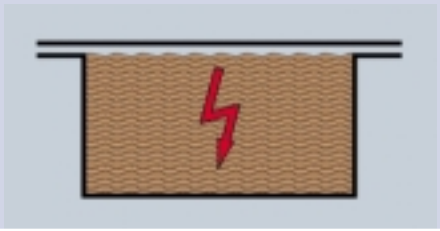
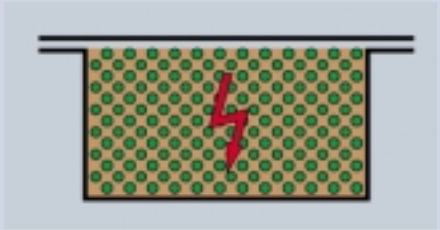
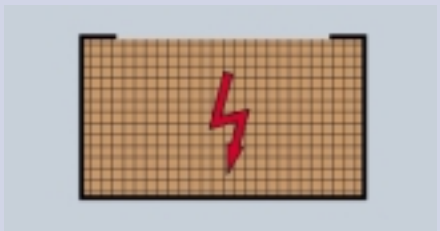
The code letter "s" is also used in Europe for non-standardized protection measures.

Temperature Classes according to IEC

Temperature class IEC/EN NEC 505-10	Max. surface temperature of equipment [°C]	Ignition temperatures of the flammable substance [°C]	Temperature class NEC 500-3 CEC 18-052
T1	450	> 450	T1
T2	300	> 300 ≤ 450	T2
	280	> 280 ≤ 300	T2A
	260	> 260 ≤ 280	T2B
	230	> 230 ≤ 260	T2C
	215	> 215 ≤ 230	T2D
T3	200	> 200 ≤ 300	T3
	180	> 180 ≤ 200	T3A
	165	> 165 ≤ 180	T3B
	160	> 160 ≤ 165	T3C
T4	135	> 135 ≤ 200	T4
	120	> 120 ≤ 135	T4A
T5	100	> 100 ≤ 135	T5
T6	85	> 85 ≤ 100	T6

Examples for the Classification of Gases and Vapours into Explosion Groups and Temperature Classes

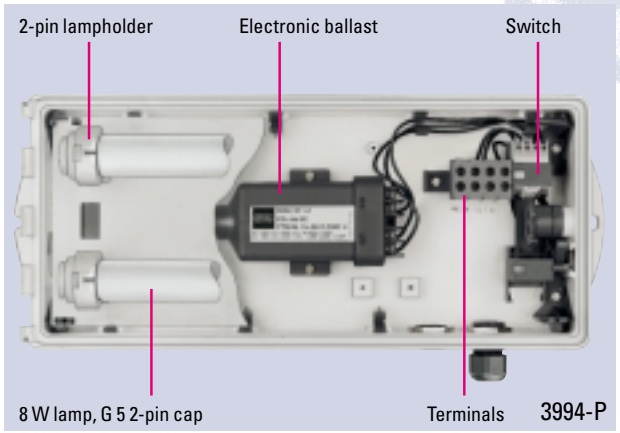
	T1	T2	T3	T4	T5	T6
I	Methane					
II A	Acetone Ethane Ethyl ethanoate Ammonia Benzol (pure) Ethanoic acid Carbon oxide Methane Methanol Propane Toluene	Ethanol i-Amyl acetate n-Butane n-Butyl alcohol	Benzine Diesel fuel Aircraft fuel Heating oils n-Hexane	Acetaldehyde Ethylether		
II B	Coal gas (lighting gas)	Ethylene				
II C	Hydrogen	Acetylene				Carbon disulphide

Type of protection in accordance with IEC or EN	Basic principle	Diagram	Main application
Flameproof enclosure **d** IEC 60 079-1 EN 50 018	Parts which can ignite a potentially explosive atmosphere are surrounded by an enclosure which withstands the pressure of an explosive mixture exploding inside the enclosure and prevents the propagation of the explosion to the atmosphere surrounding the enclosure.		Switchgear and control gear and indicating equipment, control systems, motors, transformers, heating equipment, light fittings
Increased safety **e** IEC 60 079-7 EN 50 019	Additional measures are taken to increase the level of safety, thus preventing the possibility of unacceptably high temperatures and the creation of sparks or electric arcs within the enclosure or on exposed parts of electrical apparatus parts, where such ignition sources would not occur under normal operation.		Terminal and connection boxes, control boxes for installing Ex-components (which have a different type of protection), squirrel-cage motors, light fittings
Pressurized apparatus **p** IEC 60 079-3 EN 50 016	The formation of a potentially explosive atmosphere inside a casing is prevented by maintaining a positive internal pressure of inert gas in relation to the surrounding atmosphere and, where necessary, by supplying the inside of the casing with a constant flow of inert gas which acts to dilute any combustible mixtures.		Switchgear and control cabinets, analysers, large motors
Intrinsic safety **i** IEC 60 079-11 EN 50 020	Apparatus used in a potentially explosive area contain intrinsically safe electric circuits only. An electric circuit is intrinsically safe if no sparks or thermal effects are produced under specified test conditions (which include normal operation and specific fault conditions) which might result in the ignition of a specified potentially explosive atmosphere.		Measurement and control technology, communication technology, sensors, actuators
Oil immersion **o** IEC 60 079-6 EN 50 015	Electrical apparatus or parts of electrical apparatus are immersed in a protective fluid (such as oil), such that a potentially explosive atmosphere existing over the surface or outside of the apparatus cannot be ignited.		Transformers, starting resistors
Powder filling **q** IEC 60 079-5 EN 50 017	Filling the casing of an electrical apparatus with a fine granular packing material has the effect of making it impossible for an electric arc created in the casing under certain operating conditions to ignite a potentially explosive atmosphere surrounding the casing. Ignition must not result either from flames or from raised temperature on the surface of the casing.		Transformers, capacitors, terminal boxes for heating conductors
Encapsulation **m** IEC 60 079-18 EN 50 028	Parts which may ignite a potentially explosive atmosphere are embedded in sealing compound such that the potentially explosive atmosphere cannot be ignited.		Switchgear with small capacity, control and signalling units, display units, sensors
Type of protection **n** IEC 60 079-15 EN 50 021	Electrical apparatus is not capable of igniting a potentially explosive atmosphere (under normal operation and under defined abnormal operating conditions).	Zone 2 This type of protection includes several methods of ignition protection.	All electrical apparatus for Zone 2, less suitable for switchgear and control gear

3.3.1 Application and Combination of Types of Protection "d" and "e"

The most important type of protection for switchgear is "Flameproof Enclosure", usually in conjunction with "Increased Safety". Switchgear does produce sources of ignition in normal use and therefore "Increased Safety" alone is not applicable as type of protection for switchgear, since "Increased Safety" is based on the principle to avoid sources of ignition by additional measures. However, "Increased Safety", in conjunction with "Flameproof Enclosure", cut a great figure for switchgear and control gear.

Modern, explosion protected luminaires also use a combination of several types of protection to achieve the best results with regard to safety, function and economy.



Interior design of compact light fitting C-LUX 6100

3.3.2 Applications of Type of Protection "Intrinsic Safety"

The type of protection "Intrinsic Safety" is based on the principle of current and voltage limitation within an electric circuit. The energy from a power circuit capable of causing an explosive atmosphere to ignite is thus limited to such an extent that the surrounding explosive atmosphere cannot ignite as a result of sparks or inadmissible surface heating of the electrical components.
The type of protection "Intrinsic Safety" is particularly used in measurement and control technology, as no high currents, voltage and capacities are required here.

Terms and Definitions

Intrinsically safe electrical circuit
An electric circuit in which neither a spark nor the effect of heat can cause a certain explosive atmopshere to ignite.

Intrinsically safe electrical apparatus
Electrical apparatus in which all circuits are intrinsically safe.

Associated electrical apparatus,
Electrical apparatus which contains circuits some of which are intrinsically safe and some are not, and which is designed such that the non-intrinsically safe circuits cannot negatively influence the intrinsically safe circuits.

Minimum ignition energy
The minimum ignition energy of a gas/air and vapour/air mixture is the smallest level of electrical energy which occurs while a capacitor is discharging and which may still be sufficient to ignite the most ignitable mixture of a gas or vapour and air at atmospheric pressure and 20°C. (This is tested using the spark test apparatus in accordance with EN 50 020 Appendix B).
Intrinsically safe electrical apparatus and intrinsically safe components from related equipment are classified according to categories ia or ib. Equipment from category "ia" is suitable for use in Zone 0, and equipment from category "ib" for use in Zone 1.

Category "ia"	Category "ib"
Category "ia" electrical apparatus shall not be capable of causing ignition under normal operation and if one fault occurs or if a combination of any two faults occurs.	Electrical apparatus from category "ib" shall not be able to cause the ignition of one substance during normal operation or in the event of one fault.
Safety factor 1.5: during normal operation and with one fault	Safety factor 1.5: during normal operation and with one fault
Safety factor 1.0: two independent faults	Safety factor 1.0: with one fault, if the electrical apparatus does not have unprotected switching contacts in those components which may be exposed to an explosive atmosphere, and if the fault is monitored.

Intrinsically safe apparatus	Associated electrical apparatus	
This contains intrinsically safe electric circuits only	This contains both intrinsically safe and non-intrinsically safe electric circuits	
EEx ib IIC T6	[EEx ib] IIC T6	EEx de [ib] IIC T6
All necessary information is provided such as category, gas group and temperature class.	The square brackets indicate that the associated electrical apparatus contains an intrinsically safe electric circuit which may be introduced into Zone 1, gas groups IIA, IIB and IIC.	
The apparatus may be used in Zone 1.	The apparatus must be installed outside of the potentially explosive area.	The apparatus may be used in zone 1 due to installation in a flame-proof enclosure ("d")

Isolation of Intrinsically Safe Circuits from non-intrinsically Safe Circuits

An important measure for intrinsically safe circuits is the safe isolation of all intrinsically safe circuits from non intrinsically safe circuits. Safe electric isolation is always required, with the exception of safety barriers. One rule which applies especially to Germany is that safety barriers are not permitted for the protection of intrinsically safe circuits in Zone 0. Galvanic isolation is generally required for Zone 0.

Zener diodes, used for limiting voltage, as well as other semiconductor components are considered to be susceptible to failure and must therefore be safeguarded by means of redundant components. Wire wound or sheet resistors for current limitation are considered to be infallible components (they have high resistivity in the event of a fault). Therefore one single component is sufficient.

Single fault safety:
In the event of the failure of one zener diode, a second zener diode must take its function (Category "ib": one redundant zener diode)

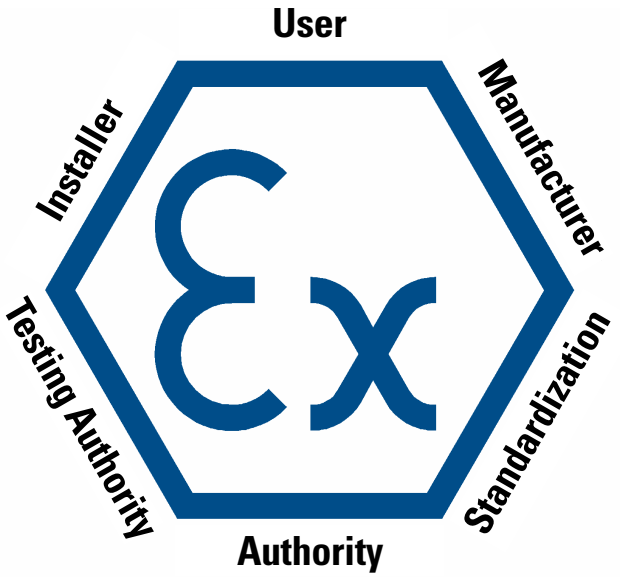
Double fault safety:
In the event of a failure of two zener diodes, a third zener diode must take its function (Category "ia": two redundant zener diodes)

Temperature field station

4. Installation and Operation of Electrical Apparatus in Potentially Explosive Areas

4.1 Duties of Installer, Manufacturer and Operator

Safety in potentially explosive areas can only be guaranteed by a close and effective working relationship amongst all parties involved.



The operator is responsible for the safety of his equipment. It is his duty to judge where there is a risk of explosion and then divide areas into Zones accordingly. He must ensure that the equipment is installed in accordance with regulations and is tested before initial use. The equipment must be kept in a fit state by regular inspection and maintenance.
The installer must observe the installation requirements and select and install the electric apparatus correctly for its intended use.
Manufacturers of explosion protected apparatus are responsible for routine testing, certification and documentation and are required to ensure that each device manufactured complies with the design tested.

4.2 Classification into Zones and Selection of Apparatus

The question of possible risks of explosion must be addressed at the early stages of planning a new facility. When classifying potentially explosive areas, the influence of natural or artificial ventilation must be considered in addition to the levels of flammable materials being released. Furthermore, the classification figures relating to explosion technology must be determined for the flammable materials being used (see Appendix 6.2). Only then a decision can be reached on the division of potentially explosive areas into Zones and the selection of suitable apparatus. IEC 60 079-14 (DIN 60 079-14) applies to the installation of electrical apparatus in potentially explosive areas Group II.

Equipment shall only be used within the ambient temperature range stipulated in its marking. If the marking does not contain any information, the standard range of between -20°C and +40°C does apply.
Electrical apparatus with the types of protection "d" and "i" must correspond to a subgroup IIA, IIB or IIC.

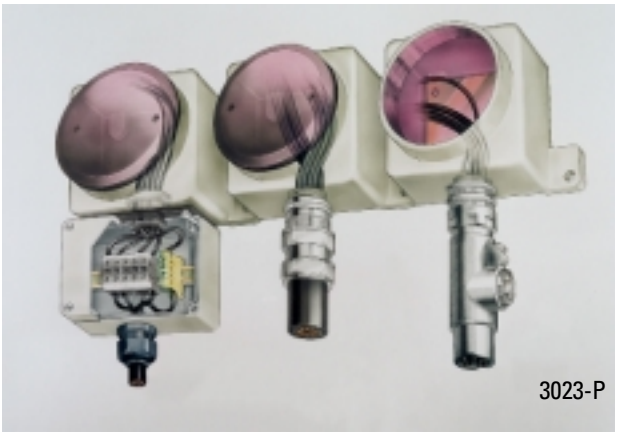
Electrical apparatus must be selected and installed such that it is protected against external influences which may adversely affect the explosion protection.

4.3 Methods of Installation

Essentially, three installation systems are used for electrical facilities in hazardous locations:

1. Cable system with indirect entry
2. Cable system with direct entry
3. Conduit system

The technical design of the electrical apparatus used with the individual types of installation is accordingly different.



The installation systems worldwide;
left: Cable system with indirect entry
centre: Cable system with direct entry
right: Conduit system

Only the conduit system or mineral insulated cables (MI) are permitted in the USA for all applications in Class 1, Division 1 in accordance with NEC 501-4, whereby the mineral insulated cables are mainly used as heating lines and fire resistant signal and control lines. Certain types of cable and line are also permitted in Division 2. A comparison of the various systems is shown below.

Cable systems
Cable systems are mainly used in Europe. For this, high-quality cables and lines are laid uncovered. It is only in areas in which mechanical damage could be expectd that they are laid in conduits which are open at both ends.

In the case of indirect entry, the cables and lines are conducted via cable entrances into a wiring space in the type of protection "Increased safety" and connected to the terminals also provided in "Increased Safety". From here, the individual wires are conducted via flameproof line ducts into the flame proof enclosure.

The line ducts are installed by the manufacturer, with the result that, by contrast with direct entry, a routine test of the factory wired flame proof enclosure can be made.
The installation engineer need only open the wiring space for the connection, not the flameproof enclosure with factory wiring.

In the case of direct entry, the connecting lines are conducted directly into the flameproof enclosure. Only cable glands which have been specially certified for this purpose may be used for this type of entry. The flexible gasket and the cable sheath must form a gap through which no flames can penetrate. For this reason, attention must be paid to the appropriate selection of cable union depending on both the type and structure of cable and installation location. The flame proof enclosure primarily depends here on the care taken by the installation engineer when laying the cables and lines.

Conduit system

In the case of installation using the conduit system, the electrical lines are drawn as single wires into enclosed metal tubes. The tubes are connected to the housings by means of unions and equipped with a seal at each entrance point. The entire conduit system is flame proof.

The aim of the seal is to prevent explosions which may occur inside the housing from penetrating the pipeline. Otherwise extremely high explosive pressures would be created as a result of pre-compression in long cylindrical tubes. For this reason, it is recommended that seals be installed not just at the entrance points but at specific intervals. Drains must be installed at low points at which condensate can accumulate.

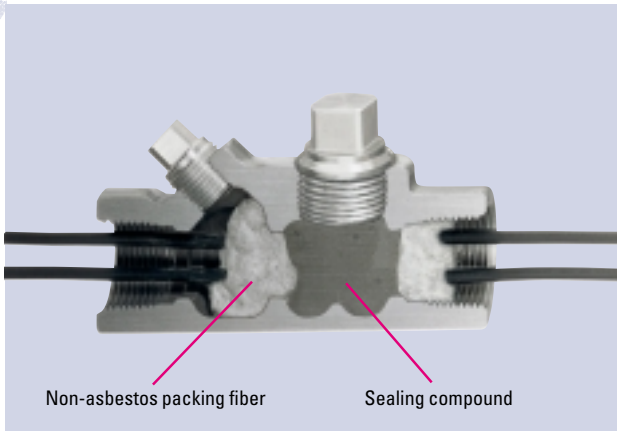
4.4 Repair and Maintenance

Regular maintenance is required to maintain the safety of electrical facilities in hazardous locations.Personnel who carry out such maintenance and repair work should work under the guidance of an explosion protection specialist and should be informed of the particular dangers involved.

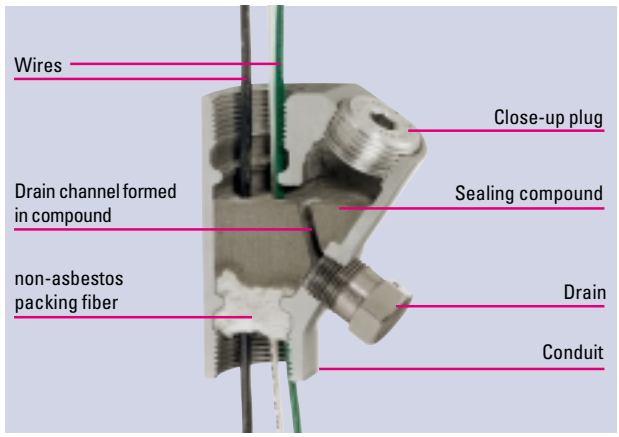
Before carrying out any modification and repair work, it must be ensured that there is no danger of explosions occurring during this work. Normally, formal written permission for this should be acquired from the company management. On completion of the work, a record should be kept of what work was carried out, and confirmation given that all relevant regulations have been observed.

A relevant specialist should check any extensive modifications which may have a negative effect on the explosion protection. This is not necessary if the manufacturer of the apparatus concerned has carried out the modification.

When exchanging components or fully assembled apparatus, the explosion and device-related characterisitc data should be noted. Only original parts from the manufacturer should be used.



Seal for horizontal installation – without drain



Seal for vertical installation – with drain

5. Explosion Protection in North America

5.1 Introduction

The basic principles of explosion protection are the same all over the world. However, technologies have developed in North America in the field of explosion protection for electrical equipment and installations which deviate considerably from those of the IEC (International Electrotechnical Commission). The differences from IEC technologies are among others the classification of hazardous locations, the construction of apparatus and the installation of electrical systems.

5.2 Classification of Hazardous Locations

For potentially explosive atmospheres the term "hazardous (classified) locations" is used in North America. They are defined in Articles 500 and 505 of the National Electrical Code (NEC) in the USA and in Section 18 and Annex J of the Canadian Electrical Code (CEC) in Canada.The hazardous locations are those locations, where fire or explosion hazards may exist due to flammable gases, vapours or liquids (Class I), combustible dusts (Class II), or ignitable fibers or flyings (Class III).

Based on the likelihood or risk that an ignitable concentration of a flammable material will be present the hazardous locations are traditionally subdivided into Division 1 and Division 2.

In 1996 the IEC classification system was introduced as a parallel system to the existing system for Class I in the USA. This system was implemented by the new Article 505. This now gives the end user the possibility to choose the system which best suits his needs.

The IEC zone classification for Class I was also introduced in Canada (CEC, 1988 edition). All newly built facilities in Canada need to be classified according to this principle.

The traditional North American classification system divides Class I flammable gases, vapours, mists and liquids into Gas Groups A, B, C and D and Class II combustible dusts into Groups E, F and G.

Group A is the most hazardous gas group in the traditional NEC system whereas Group IIC is the most volatile in the IEC system in Article 505 of the NEC.

In Canada both gas grouping systems may be used with the zone classification system.

The maximum surface temperature classification given in the new Article 505 maintains a pure IEC approach of having six main temperature classes T1 to T6. This deviates from the traditional NEC temperature class structure which has further subdivisions between the main temperature classes. In the 1998 CEC this traditional structure T1-T6 with intermediate subdivisions was maintained.

5.3 Regulations for Installation

The National Electrical Code in the USA and the Canadian Electrical Code in Canada apply to electrical apparatus and installations for hazardous locations.

These have the character of installation regulations for electrical facilities in all locations and refer to a number of further standards of other institutions which contain specifications for the installation and construction of suitable equipment.

The methods of installation for the zone concept in accordance with the NEC are similar to the traditional Class/Division system. New to the NEC 1996 is the use of listed Metal Clad (MC) cables in addition to rigid conduit and Mineral Insulated cables in Class I, Division 1 or Zone 1.

One significant advantage of the CEC is the increased possibility of using wires and cables. In contrast to the USA, Canada has, for some time now, also permitted the use of special cables similar to the IEC steel-wire armoured cables.

5.4 Constructional Requirements

The regulations of the National Electrical Code and the Canadian Electrical Code stipulate which apparatus and methods of protection may be used in different hazardous locations.

Various standards and regulations govern the construction and testing of explosion-protected electrical apparatus and installations in North America. In the USA, these are mainly the standards issued by Underwriters Laboratories Inc. (UL), Factory Mutual Research Corporation (FM) and the International Society for Measurement and Control (ISA). In Canada, those of the Canadian Standards Association (CSA) apply.

The tables in appendix 6.4 provide an overview of the constructional requirements for hazardous locations and methods of protection.

5.5 Degrees of Protection provided by Enclosures

The standard IEC 60 529 defines the degrees of protection provided by enclosures. In the USA the degrees of protection are included in the NEMA Publication No. 250 (National Electrical Manufacturing Association). These enclosure types could not be exactly equated with the IEC enclosure classification designation since NEMA additional environmental influences (such as cooling lubricant, cutting coolant, corrosion, iceing, hail) takes into account.

NEMA Enclosure Type Numbers	IEC Enclosure Classification
1	IP 10
2	IP 11
3	IP 54
3R	IP 14
3S	IP 54
4 and 4X	IP 56
5	IP 52
6 and 6P	IP 67
12 and 12K	IP 52
13	IP 54

Note:
As the NEMA Types meet or exceed the test requirements for the associated IEC Classifications the table cannot be used to convert from IEC Classifications to NEMA Types.

5.6 Certification and Marking

In the USA and Canada, electrical apparatus and apparatus used in hazardous locations are, as a rule, subject to approval. Exceptions to this are items of electrical apparatus which, due to their design and the type of the explosive atmosphere in which they operate, cannot create sparks. The responsible authorities shall decide whether such equipment is subject to approval.

Equipment which has been developed and manufactured for use in hazardous locations is tested and approved in the USA and Canada by a recognized testing laboratory. In the USA, this is for example the Underwriters Laboratories or Factory Mutual and in Canada the Canadian Standards Association.

In addition to data such as manufacturer, model, serial number and electrical data, any data relating to explosion protection must be shown on the marking of the equipment. The requirements for this are specified in the NEC, the CEC as well as the relevant construction regulations of the testing authority.

Class I, II & III, Division 1 and 2

The approved electrical equipment for Class I, Class II and Class III, Division 1 and Division 2 must be marked to show the following information:
1. Class(es), Division(s) (optional except for Division 2)
2. Gas/dust group(s)
3. Operating temperature or temperature class (optional T5 and T6

Example: Class I Division 1 Groups C D T6

Class I, Zone 0, 1 and 2

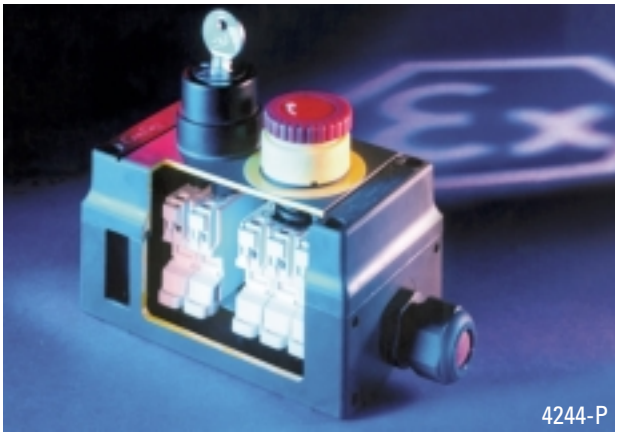
For equipment intended for use in Class I, Zone 0, Zone 1 or Zone 2, a distinction is made between "Division Equipment" and "Zone Equipment".

(1) **Division Equipment:** Equipment approved for Class I, Division 1 and/or Class I, Division 2 shall be permitted to be marked with the following in addition:
1. Class I, Zone 1 or Class I, Zone 2 (as applicable)
2. Gas group(s) IIA, IIB or IIC
3. Temperature class

Example: Class I Zone 1 IIC T4

(2) **Zone Equipment:** Equipment meeting one or more of the protection techniques described in Article 505 of the NEC or Section 18 of the CEC shall be marked with the following in the order shown:
1. Class (optional in Canada)
2. Zone (optional in Canada)
3. AEx (USA) or Ex or EEx (Canada)
4. Method(s) of protection
5. Equipment group II or applicable gas group(s) IIA, IIB or IIC
6. Temperature class

Example: Class I Zone 0 AEx ia IIC T6



Control and Signal Station
ConSig 8040

6. Appendix

6.1 Comparison of IEC Publications and European Standards (EN)

Electrical Apparatus for Explosive Gas Atmospheres

IEC publications	EN	
IEC 60079-0	EN 50 014	General requirements
IEC 60079-1	EN 50 018	Construction and verification test of flameproof enclosures of electrical apparatus
IEC 60079-1A	-----	Method of test for ascertainment of maximum experimental safe gap
IEC/TR 60079-2	EN 50 016	Electrical apparatus, type of protection 'p'
IEC 60079-3	EN 50 020	Spark-test apparatus for intrinsically-safe circuits
IEC 60079-4 IEC 60079-4A	-----	Method of test for ignition temperature
IEC 60079-5	EN 50 017	Powder filling 'q'
IEC 60079-6	EN 50 015	Oil-immersion 'o'
IEC 60079-7	EN 50 019	Increased safety 'e'
IEC 60079-10	EN 60079-10	Classification of hazardous areas
IEC 60079-11	EN 50 020	Intrinsic safety 'i'
IEC 60079-12	EN 50 014	Classification of mixtures of gases or vapours with air according to their maximum experimental safe gaps and minimum ignition currents
IEC/TR 60079-13	-----	Construction and use of rooms or buildings protected by pressurization
IEC 60079-14	EN 60079-14	Electrical installations in hazardous areas (other than mines)
IEC 60079-15	pr EN 50 021	Electrical apparatus with type of protection 'n'
IEC/TR 60079-16		Artificial ventilation for the protection of analyser(s) houses
IEC 60079-17	EN 60079-17	Inspection and maintenance of electrical installations in hazardous areas (other than mines)
IEC 60079-18	EN 50 028	Encapsulation 'm'
IEC 60079-19	prEN 60079-19	Repair and overhaul for apparatus used in potentially explosive atmospheres (other than mines or explosives)
IEC/TR 60079-20	-----	Data for flammable gases and vapours, relating to the use of electrical apparatus

Electrical Apparatus for Use in the Presence of Combustible Dust

IEC publications	EN	
IEC 61241-1-1	-----	Part 1: Electrical apparatus protected by enclosures Section 1: Specification for apparatus
IEC 61241-1-2	-----	Part 1: Electrical apparatus protected by enclosures Section 2: Selection, installation and maintenance
IEC 61241-2-1	-----	Part 2: Test methods Section 1: Methods for determining the minimum ignition temperatures of dust
IEC 61241-2-2	EN 61241-2-2	Part 2: Test methods Section 2: Method for determining the electrical resistivity of dust in layers
IEC 61241-2-3	-----	Part 2: Test methods Section 3: Method for determining minimum ignition energy of dust/air mixtures
IEC 61241-3	-----	Part 3: Classification of areas where combustible dust are or may be present

6.2 Safety Ratings of Flammable Gases and Vapours

Material	Ignition temperature °C	Temperature class	Gas group
1,2-dichloroethane	440	T 2	II A
Acetaldehyde	140	T 4	II A
Acetone	540	T 1	II A
Acetylene	305	T 2	II C (3)
Ammonium	630	T 1	II A
Benzins, petrol fuels Boiling point < 135 °C	220 to 300	T 3	II A
Benzole (pure)	555	T 1	II A
CyclohexanOne	430	T 2	II A
Diesel fuels (DIN 51601)	220 to 300	T 3	II A
Jet fuels	220 to 300	T 3	II A
Acetic acid	485	T 1	II A
Acetic anhydride	330	T 2	II A
Ethane	515	T 1	II A
Ethyl ethanoate	460	T 1	II A
Ethanol	425	T 2	II A / II B
Ethyl chloride	510	T 1	II A
Ethene	425	T 2	II B
Ethylene oxide	440 (self-decomposing)	T 2	II B
Diethyl ether	170	T 4	II B
Ethyl glycol	235	T 3	II B
EL fuel oil (DIN 51603)	220 to 300	T 3	II A
L fuel oil (DIN 51603)	220 to 300	T 3	II A
M and S fuel oils (DIN 51603)	220 to 300	T 3	II A
i-Amyl acetate	380	T 2	II A
Carbon monoxide	605	T 1	II A / II B
Methane	595 (650)	T 1	II A
Methanol	455	T 1	II A
Methyl chloride	625	T 1	II A
Naphthalene	540	T 1	II A
n-Butane	365	T 2	II A
Butanol	340	T 2	II A
n-Hexane	240	T 3	II A
n-Propyl alcohol	405	T 2	-*)
Oleic acid	360 (self-decomposing)	T 2	-*)
Phenol	595	T 1	II A
Propane	470	T 1	II A
Carbon disulphide	95	T 6	II C (1)
Hydrogen sulphide	270	T 3	II B
Special benzines Boiling point > 135 °C	200 to 300	T 3	II A
Coal gas (lighting gas)	560	T 1	II B
Tetralin (1,2,3,4-tetrahydronaphthalene)	425	T 2	-*)
Toluol	535	T 1	II A
Hydrogen	560	T1	II C (2)

Extract from the tabular work "Sicherheitstechnische Kennzahlen brennbarer Gase und Dämpfe [Safety ratings of flammable gases and vapours]"
by K. Nabert and G. Schön - (6th edition)
-*) The gas group for this substance has not yet been determined.
(1) Also gas groups II B + CS2
(2) Also gas groups II B + H2
(3) Also gas groups II B + C2 H2

6.3 Classification of Hazardous Locations in North America

Gases, Flammable Vapours or Mists Class I Area Classification		**Combustible Dusts, Class II Area Classification**	**Fibres and Ignitable Flyings Class III Area Classification**
NEC 500-5 CEC J18-004	NEC 505-7 CEC 18-006	NEC 500-6 CEC 18-008	NEC 500-7 CEC 18-010
Division 1 Locations where ignitable concen-t rations of flammable gases, vapours or liquids can exist all the time or some of the time under normal operating conditions.	Zone 0 Locations where ignitable concentrations of flammable gases, vapours or liquids can exist all the time or for long periods of time under normal operating conditions.	Division 1 Locations where ignitable concentrations of combustible dusts can exist all the time or some of the time under normal operating conditions.	Division 1 Locations where ignitable fibres or materials producing combustible flyings are handled, manufactured or used .
	Zone 1 Locations where ignitable concentrations of flammable gases, vapours or liquids can exist some of the time under normal operating conditions.		
Division 2 Locations where ignitable concentrations of flammable gases, vapours or liquids are not likely to exist under normal operating conditions.	Zone 2 Locations where ignitable concentrations of flammable gases, vapours or liquids are not likely to exist under normal operating conditions.	Division 2 Locations where ignitable concentrations of combustible dusts are not likely to exist under normal operating conditions.	Division 2 Locations where easy ignitable fibres are stored or handled.
Class I Groups		**Class II Groups**	**Class III Groups**
NEC 500-3 CEC J18-050	NEC 505-7 CEC 18-050	NEC 500-3 CEC 18-050	
Divisions 1 and 2 A (acetylene) B (hydrogen) C (ethylene) D (propane)	Zones 0, 1 and 2 IIC (acetylene + hydrogen) IIB (ethylene) IIA (propane)	Divisions 1 and 2 E (metal) F (coal) G (grain)	Divisions 1 and 2 none
Class I Temperature Classes		**Class II Temperature Classes**	**Class III Temperature Classes**
Divisions 1 and 2	**Zones 0, 1 and 2**	**Divisions 1 and 2**	**Divisions 1 and 2**
T1 (≤450°C)	T1 (≤450°C)	T1 (≤450°C)	none
T2 (≤300°C)	T2 (≤300°C)	T2 (≤300°C)	
T2A, T2B, T2C, T2D (≤280°C, ≤260°C, ≤230°C, ≤215°C)	--	T2A, T2B, T2C, T2D (≤280°C, ≤260°C, ≤230°C, ≤215°C)	
T3 (≤200°C)	T3 (≤200°C)	T3 (≤200°C)	
T3A, T3B, T3C (≤180°C, ≤165°C, ≤160°C)	--	T3A, T3B, T3C (≤180°C, ≤165°C, ≤160°C)	
T4 (≤135°C)	T4 (≤135°C)	T4 (≤135°C)	
T4A (≤120°C)	--	T4A (≤120°C)	
T5 (≤100°C)	T5 (≤100°C)	T5 (≤100°C)	
T6 (≤85°C)	T6 (≤85°C)	T6 (≤85°C)	

6.4 Constructional Regulations for North America

	Area	Type of ignition protection	Applicable standards for approval UL	FM	CSA
Class I	Zone 0	• Intrinsically safe, ia (2 fault)	UL 2279, Pt. 11	FM 3610	CSA-E-79-11
		• Class I, Div.1 intrinsically safe (2 fault)	ANSI/UL 913	FM 3610	
	Zone 1	• Encapsulation, m	UL 2279, Pt. 18	FM 3614 (ISA S12.23.01)	CSA-E-79-18
		• Flameproof, d	UL 2279, Pt. 1	FM 3618 (ISA S12.22.01)	CSA-E-79-1
		• Increased safety, e	UL 2279, Pt. 7	FM 3619 (ISA S12.16.01)	CSA-E-79-7
		• Intrinsically safe, ib (1 fault)	UL 2279, Pt. 11	FM 3610	CSA-E-79-11
		• Oil immersion, o	UL 2279	FM 3621 (ISA S12.26.01)	CSA-E-79-6
		• Powder filling, q	UL 2279	FM 3622 (ISA S12.25.01)	CSA-E-79-5
		• Purged pressurized, p	UL 2279, Pt. 2	(IEC 79-2)	CSA-E-79-2
		• Any Class I, Zone 0 method	--	--	--
		• Any Class I, Div. 1 method	--	--	--
	Zone 2	• Nonincendive, nC	UL 2279, Pt. 15	(ISA S12.12.01, IEC 79-15)	CSA-E-79-15
		• Non-sparking device, nA	UL 2279, Pt. 15	(ISA S12.12.01, IEC 79-15)	CSA-E-79-15
		• Restricted breathing, nR	UL 2279, Pt. 15	(ISA S12.12.01, IEC 79-15)	CSA-E-79-15
		• Hermetically sealed, nC	UL 2279, Pt. 15	(ISA S12.12.01, IEC 79-15)	CSA-E-79-15
		• Any Class I, Zone 0 or 1 method	--	--	--
		• Any Class I, Div. 1 or 2 method	--	--	--
	Divison 1	• Explosionproof	ANSI/UL 1203	FM 3615	CSA 22.2 No. 30
		• Intrinsically safe (2 fault)	ANSI/UL 913	FM 3610	CSA 22.2 No. 157
		• Purged/pressurized (Type X or Y)	ANSI/NFPA 496	FM 3620	ANSI/NFPA 496
	Division 2	• Nonincendive	UL 1604	FM 3611	CSA 22.2 No. 213
		• Non-sparking device	UL 1604	FM 3611	CSA 22.2 No. 213
		• Purged/pressurized (Type Z)	ANSI/NFPA 496	FM 3620	ANSI/NFPA 496
		• Hermetically sealed	UL 1604	FM 3611	CSA 22.2 No. 213
		• Any Class I, Div. 1method	--	--	--
		• Any Class I, Zone 0, 1 or 2 method	--	--	--
Class II	Division 1	• Dust-ignition proof	ANSI/UL 1203	FM 3616	CSA 22.2 No. 25 or
					CSA-E 1241-1-1
		• Intrinsically safe	ANSI/UL 913	FM 3610	CSA 22.2 No.157
		• Pressurized	ANSI/NFPA 496	FM 3620	ANSI/NFPA 496
	Division 2	• Dust tight	UL 1604	FM 3611	CSA 22.2 No. 25 or
					CSA-E 1241-1-1
		• Nonincendive	UL 1604	FM 3611	---
		• Non-sparking	UL 1604	FM 3611	---
		• Pressurized	ANSI/NFPA 496	FM 3620	ANSI/NFPA 496
Class III		• Any Class II, Div. 1 method	--	--	--
	Division 1	• Dust tight	Ul 1604	FM 3616	CSA 22.2 No.157
		• Intrinsically safe	ANSI/UL 913	FM 3611	CSA 22.2 No.157
	Division 2	• Dust tight	UL 1604	FM 3611	CSA 22.2 N0.157
		• Any Class II Div. 1 and Class III method	--	--	--

6.5 Ingress Protection Codes in accordance with IEC 60 529 - IPXX

Table 1: Scope of Protection for the IP Protection Classes

Digit	First digit		Second digit
	Physical protection	**Foreign body protection**	**Water protection**
0	No protection	No protection	No protection
1	Protection against back of hand contact	Protection against solid foreign bodies 50 mm diameter	Protection against water drops falling vertically
2	Protection against finger contact	Protection against solid foreign bodies 12.5 mm diameter	Protection against water drops falling at an angle (15°)
3	Protection against contact from tools	Protection against solid foreign bodies 2.5 mm diameter	Protection against water-spray at an angle up to 60°
4	Protection against contact with a wire	Protection against solid foreign bodies 1.0 mm diameter	Protection against water spray from all directions
5	Protection against contact with a wire	Protection against dust	Protection against water jets
6	Protection against contact with a wire	Dust-tight	Protection against strong water jets
7	-	-	Protection against intermittent immersion in water
8	-	-	Protection against continuous immersion in water

6.6 Degree of Protection provided by Enclosures according to NEMA (Publication No. 250 Enclosures for Electrical Equipment 1000 Volts Maximum)

Enclosure Type	**Degree of Protection**	**Use**
Type 1	Protection against limited amounts of falling dirt	Indoor
Type 2	Protectionn against limited amounts of falling water and dirt	Indoor
Type 3	Protection against rain, sleet, windblown dust, and damage for external ice formation	Outdoor
Type 3R	Protection against rain, sleet, and damage for external ice formation	Outdoor
Type 3S	Protection against rain, sleet, windblown dust, and for operation of external mechanisms when ice laden	Outdoor
Type 4	Protection against windblown dust and rain, splashing water, hose directed water, and damage from external ice formation	Indoor or Outdoor
Type 4X	Protection against corrosion, windblown dust and rain, splashing water, hose directed water, and damage from external ice formation	Indoor or Outdoor
Type 5	Protection against settling airborne dust, falling dirt, and dripping noncorrosive liquids	Indoor
Type 6	Protection against hose directed water, the entry of water during occasional temporary submersion at a limited depth, and damage from external ice formation	Indoor or Outdoor
Type 7	For use in locations classified as Class I, Groups A, B, C, or D as defined in the NEC	Indoor
Type 8	For use in locations classified as Class I, Groups A, B, C, or D as defined in the NEC	Indoor or Qutdoor
Type 9	For use in locations classified as Class II, Groups E, F, G as defined in the NEC	Indoor
Type 10	Constructed to meet the applicable requirements of the Mine Safety Health Administration	Mining
Type 11	Protection against the corrosive effects of liquids and gases by oil immersion	Indoor
Type 12, 12K	Protection against circulating dust, falling dirt, and dripping non corrosive liquids	Indoor
Type 13	Protection against dust, spraying of water, oil, and non corrosive coolant	Indoor

6.7 Overview of the most important Approval and Testing Authorities *

Country	Approval authority	Testing authority
Australia	Quality Assurance Services R Jacobi Locked Bag 2032 STRATHFIELD NSW 2135 Tel: +61 2 9746 4900 Fax: +61 2 9746 8460	International Testing and Certification Services (ITACS) 2 Second Street BOWDEN S A 5007 Tel: +61 8 83468680 Fax: +61 8 83467072 WorkCover Authority of NSW Londonderry Occupational Safety 919 Londonderry Road LONDONDERRY NSW 2753 Tel: +61 47 244 900 Fax: +61 47 244 999
	Safety in Mines Testing and Research Station (SIMTARS) 2 Smith Street REDBANK QLD 4075 Tel: +61 7 3810 6370 Fax: +61 7 3810 6366	
Austria	TÜV ÖSTERREICH Krugerstraße 16 A 1015 Wien Tel: +43 1 514 07 0 Fax: +43 1 514 07 240	
Brazil	CENTRO DE PESQUISAS DE ENERGIA ELETRICA (CEPEL) Cx. Postal 2754 CEP 20001 Rio de Janeiro - RJ Tel: +5521 598 2442 Fax: +5521 598 2443	
Canada	Canadian Standards Association (CSA) 178 Rexdale Boulevard Etobicoke, Ontario M9W 1R3 Tel: +416 747 4000 Fax: +416 747 4149 CANMET 555 Booth Street Ottawa, Ontario K1A 0G1 Tel: +613 947 6580 Fax: +613 947 4198	
China	Centre for Explosion Protection and Safety of Instrumentation (NEPSI) 103 Cao Bao Road Shanghai Tel: +21 643 86180 Fax: +21 643 335 66	
Czech Republic	Fyzikalne technicky zkusebni ustav (FTZU) Statni zkusebna c. 210 CZ 71607 Ostrava-Radvanice Tel: +42 69 6215484 Fax: +42 69 214860	
Denmark	DEMKO Lyskaer 8 DK-2730 HERLEV Tel: +45 44 947 266 Fax: +45 44 947 261	
Federal Republic of Germany	Physikalisch-Technische Bundesanstalt (PTB) Bundesallee 100 D 38116 Braunschweig Tel: +49 531 592 3400 Fax: +49 531 592 3405 DMT - Gesellschaft für Forschung und Prüfung mbH Fachstelle für Sicherheit elektrischer Betriebsmttel Bergbau-Versuchsstrecke (BVS) Beylingstr. 65 D 44329 DORTMUND Tel: +49 231 2491 0 Fax: +49 231 2491 224	

Country	Approval authority	Testing authority
		IBExU - Institut für Sicherheitstechnik GmbH Institut an der Bergakademie Freiberg Fuchsmühlenweg 7 D 09599 FREIBERG Tel: +49 3731 3805 19 Fax: +49 3731 23650 TÜV Hannover/Sachsen-Anhalt e.V. P.O.Box 81 05 51 D 30505 Hannover Tel: +49 511 986 1552 Fax: +49 511 986 1590 FSA - Forschungsgesellschaft für angewandte Systemsicherheit und Arbeitsmedizin mbH Dynamostraße 7-11 D 68165 Mannheim Tel: +49 621 44 56 36 06 Fax: +49 621 44 56 34 02
Finland	Technical Research Centre of Finland (VTT) Automation/Electrotechnical Testing Otakaari 7B, Espoo P.O. Box 13051 FIN 02044 Vtt Tel: +358 9 4561 Fax: +358 9 4567042	
France	Laboratoires Central des Industries Electriques (LCIE) 33 avenue du Général Leclerc F 92260 Fontenay-aux-Roses Tel: +33 1 409 55519 Fax: +33 1 409 55520 Institut National de l'Environnement Industriel et des Risques (INERIS) B Piquette Parc Technologique ALATA - B.P.2 F-60550 Verneuil-En-Halatte Tel: + 3 44 55 66 77 Fax: +3 44 55 66 99 E-Mail: ineris@ineris.fr	
Great Britain	Electrical Equipment Certification Services (EECS) Health and Safety Executive Harpur Hill BUXTON DERBYSHIRE SK17 9JN Tel: +44 1 298 28000 Fax: +44 1 298 28244	Explosion and Fire Hazards Laboratory ERA Technology Ltd G R Oliver Cleeve Road LEATHERHEAD SURREY KT 7SA Tel: +44 1372 367 000 Fax: +44 1372 367 099
	SIRA Certification Service (SCS) South Hill M Shearman CHISELHURST KENT BR7 5EH Tel: +44 181 467 2636 Fax: +44 181 295 1990	SIRA Test and Certification Ltd Saighton Lane A J McMillan GB - Chester CH3 6EG Tel: +44 1244 332200 Fax: +44 1244 332112
Hungary	Hungarian testing authority for explosion-proof electrical apparatus (BKI) Mikoviny S. u. 2-4 H 1037 Budapest Tel: +36 1 168 7260 Fax: +36 1 250 1720	
Italy	Centro Elettrotecnico Sperimentale Italiano (CESI) Via Rubattino 54 I 20134 Milano Tel: +39 2 212 53 72 Fax: +39 2 212 54 40	

*) where no approval authority is given,
the testing authority is also the approval authority

Country	Approval authority / Testing authority
Japan	The Technical Institution of Industrial Safety (TIIS) 1-4-6 Umezono Kiyose Tokyo 204 Tel: +81 424 91 4514 Fax: +81 424 95 2461
Luxemburg	Service de l´Energie de l´Etat Luxembourgeois B.P. 10 L 2010 Luxembourg Tel: +352 46 97 48 Fax: +352 22 25 24
Netherlands	KEMA Postbus 9035 NL 6800 ET ARNHEM Tel: +31 26 3 56 34 28 Fax: +31 26 3 51 01 78
Norway	NEMKO P O Box 73 Blindern N 0314 OSLO Tel: +47 22 960330 Fax: +47 22 698636
Poland	Glowny Institut Gornictwa Kopalnia Doswiadczalna "BARBARA" ul. Podleska 72, skrytka pocztowa 72 PL 43-190 Mikolow Tel: +58 2028 024 9 Fax: +58 2028 745
Republic Korea	Korea Industrial Safety Corp. (KISCO) 34-4 Kusa-dong, Poopyoung-gu Inchon 403-120 The Republic of Korea Tel: +82 32 5100 865 Fax: +82 32 518 6483-4
Rebublic of South Africa	South African Bureau of Standards (SABS) 1 Dr. Lategan Road, Groenkloof, Pretoria Private Bag X191 Pretoria 0001 Tel: +12 428 7911 Fax: +12 344 1568
Romania	INSEMEX PETROSANI Equipment Ex. Certification Service Str. Gen. Vasile Milea nr.32-34 Cod 2675 Petrosani. Tel: +4 054 541 621 Fax: +4 054 232 277
Russia	Test centre for explosion-proof electrical apparatus (VNIIEF) formerly Arzamas 16 Prospect Mira, 37 607190 Sarov Tel: +831 30 45669 Fax: +831 30 45530
Slovakia	Elektrotechnicky vyskumny a projektovy ustav (EVPU) Statna skusobna SKTC 101 SK 01851 Nova Dubnica Tel: + Fax: +
Slovenia	Mr Igor Likar Slovenian Institute of Quality and Metrology (SIQ) Trazaska cesta 2 SL-1000 Ljubljana Tel: +386 61 177 8100 Fax: +386 61 177 8444
Spain	Laboratorio Official Jose Maria Madariaga (LOM) Calle Alenzaa 1-2 E 28003 Madrid Tel: +34 1 442 13 66 Fax: +34 1 441 99 33

Country	Approval authority	Testing authority
Sweden	Swedish National Testing and Research Institute (SP) Brinellgatan 4 Box 857 S-501 15 BORAS Tel: +46 33 16 5000 Fax: +46 33 13 5502	
Switzerland	Eidgenössisches Starkstrominspektorat (ESTI) Luppmenstraße 1 CH 8320 FEHRALTORF Tel: +41 1 956 12 12 Fax: +41 1 956 12 22	Schweizerischer Elektrotechnischer Verein (SEV) Luppmenstraße 1 CH 8320 FEHRALTORF Tel: +41 1 956 11 11 Fax: +41 1 956 11 12
Ukraine	Test and certification centre for explosion-proof and flame-proof electrical apparatus (ISZ VE) ul. Gvardeiskoi Divisii 17 340052 Donezk Tel: + Fax: +	
USA	Underwriters Laboratories Inc. (UL) 333 Pfingsten Road Northbrook, IL 60062-2096 Tel: +847 272 8800 Fax: +847 272 8129 Factory Mutual Research Corporation (FM) 1151 Boston-Providence Turnpike P.O. Box 9102 Tel: +781 255 4840 Fax: +781 762 9375	
Yugoslavia	SAVEZNO MINISTARSTVO ZA RAZVOJ, NAUKU i ZIVOTNU SREDINU SAVEZNI ZAVOD ZA STANDARDIZACIJU (SZS) Federal Ministry for Development, Science and Environment Federal Institution for Standardization Kneza Milosa 20 YU Beograd Tel: +11 681 999 Fax: +235 10 36	

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