TECHNICAL SOLUTIONS APPLICABLE TO ELECTRICAL EQUIPMENTS DESIGNED FOR USE IN EXPLOSIVE GAS ATMOSPHERES

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REZUMAT. Riscul de explozie este un aspect important atunci când sunt avute în vedere instalaţii tehnologice utilizate la extragerea resurselor energetice existente (sub formă solidă - cărbuni, formă lichidă - petrol sau formă gazoasă - gaze naturale), procesarea, stocarea sau transportul acestora sau a substanţelor combustibile rezultate. Pentru a face posibilă utilizarea unui echipament tehnic în astfel de zone (cu pericol de atmosfere explozive) acestea trebuie prevăzute cu caracteristici speciale în scopul prevenirii aprinderii atmosferei explozive în care sunt instalate.

Cuvinte cheie: atmosferă explozivă, echipament, risc de explozie.

ABSTRACT. Risk of explosion represents an important aspect when referring to technological installations used for extraction of existing energetic resources (in solid form – coal, liquid form – oil or gaseous form – natural gases), processing, storage or transport of them or of the resulting combustible substances. To enable the use of technical equipment in such areas (with hazard of explosive atmospheres), they must be equipped with special features so as to prevent ignition of explosive atmosphere in which are installed.

Keywords: explosive atmosphere, equipment, risk of explosion

1. INTRODUCTION

The risk of explosion represents an important aspect when referring to technological installations used for extraction of existing energetic resources (in solid form – coal, liquid form – oil or gaseous form – natural gases), processing, storage or transport of them or of the resulting combustible substances. An important aspect on which the risk of explosion depends is represented by the ignition-explosion probability. Taking into account the concurrent factors required for an ignition – explosion: hazardous atmosphere and ignition source; results that the ignition – explosion probability depends on the probabilities product which quantifies the chances of formation (occurrence) of an explosive atmosphere and the occurrence of a dangerous malfunction (which can represent an ignition source).

The use of technological installations for extraction of existing energetic resources (in solid form – coal, liquid form – oil or gaseous form – natural gases), processing, storage or transport of them or of the resulting combustible substances involves a probability for the combustible substances to be released.

In order to generate an explosion three factors must coexist simultaneously, in the same time and in the same space. These factors form the explosion hazard triangle (Fig. 1):

- presence of flammable substances in form of gases, vapours, mists or combustible dusts;
- presence of oxidizing substance, air or oxygen, as a support for violent combustion (explosion);
- presence of ignition source.

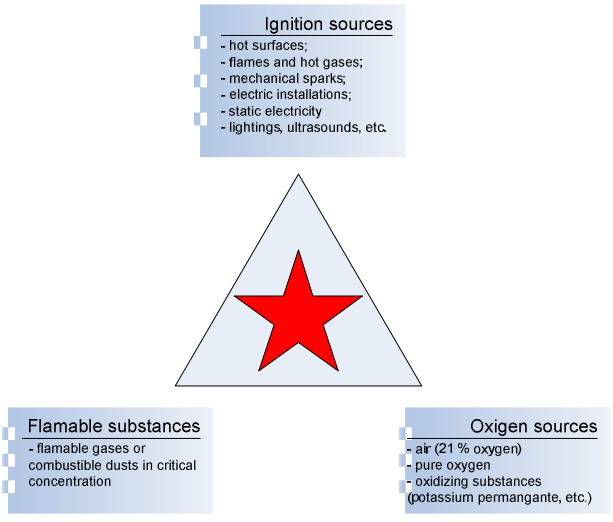

Fig.1 Ignition triangle

2. EQUIPMENT CLASSIFICATION ACCORDING ATEX DIRECTIVE 94/9/EC

Equipments that operate in hazardous explosive atmospheres must be subjected to certification procedures, according ATEX Directive 94/9/EC [16] (transposed in Romanian legislation by Government Decision no. 752/2004).

According to [16], the equipments that operate in hazardous explosive atmospheres are classified in two groups:

- Group I – equipment intended for use in mines susceptible to firedamp (underground mines susceptible to firedamp);
- Group II – equipment intended for use in places with an explosive atmosphere other than mines susceptible to firedamp (flammable gases, vapours or mists; or combustible dusts);

Equipments intended for use in mines susceptible to firedamp (Group I equipments), according ATEX Directive, are divided in two categories:

- Category M1 - identifies equipment that must continue to operate when a potentially explosive atmosphere is present;
- Category M2 - identifies equipment that does not operate when a potentially explosive atmosphere is present.

Equipments intended for use in places with an explosive atmosphere other than mines susceptible to firedamp are classified, according ATEX Directive, as follows:

- Category 1G – equipment which is intended for use in places in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently;
- Category 2G - equipment which is intended for use in places in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally;
- Category 3G - equipment which is intended for use in places where an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only;
- Category 1D – equipment which is intended for use in places in which an explosive atmosphere consisting of a mixture with air of combustible substances in the form of dust is present continuously or for long periods or frequently;
- Category 2D - equipment which is intended for use in places in which an explosive atmosphere consisting of a mixture with air of combustible substances in the form of dust is likely to occur in normal operation occasionally;
- Category 3D - equipment which is intended for use in places where an explosive atmosphere consisting of a mixture with air of combustible substances in the form of dust is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

If electrical equipment is to be placed in a hazardous explosive area, this shall be designed, manufactured and operated so as not to cause the ignition of the surrounding explosive atmosphere. There are three basic approaches to provide explosion protection to electrical circuits in hazardous location:

- Explosion confinement
- Ignition source isolation
- Energy limitation.

On this approaches are based also the types of protection applied to electrical which represents the specific measures applied to electrical equipment in order to avoid ignition of a surrounding explosive atmosphere in which these equipments are designed to operate.

4. TYPES OF PROTECTION AND EQUIPMENT CLASSIFICATION ACCORDING EUROPEAN STANDARDS

The known types of protection, for which standardized prescription exists, are [1]:

- flameproof enclosure “d” - type of protection in which the parts which can ignite an explosive atmosphere are placed in an enclosure which can withstand the pressure developed during an internal explosion of an explosive mixture and which prevents the transmission of the explosion to the explosive atmosphere surrounding the enclosure [5]
- increased safety “e” - type of protection applied to electrical equipment in which additional measures are applied so as to give increased security against the possibility of excessive temperatures and of the occurrence of arcs and sparks in normal service or under specified abnormal condition [9]
- intrinsic safety “i” - type of protection based upon the restriction of electrical energy within equipment and of interconnecting wiring exposed to an explosive atmosphere to a level below that which can cause ignition by either sparking or heating effects [11]
- pressurization “p” - technique of guarding against the ingress of the external atmosphere into an enclosure by maintaining a protective gas therein at a pressure above that of the external atmosphere [6]
- encapsulation “m” - type of protection in which the parts which could ignite an explosive atmosphere by

either sparking or heating are enclosed in a compound in such a way that this explosive atmosphere cannot be ignited [13]

o oil immersion "o" - type of protection in which the electrical equipment or parts of the electrical equipment are immersed in a protective liquid in such a way that an explosive atmosphere which may be above the liquid or outside the enclosure cannot be ignited [8]

o powder filling "q" - type of protection in which the parts capable of igniting an explosive atmosphere are fixed in position and completely surrounded by filling material to prevent the ignition of an internal explosive atmosphere [7]

o type of protection "n" (non-incendive) - type of protection applied to electrical equipment such that, in normal operation and in certain specified abnormal conditions, it is not capable of igniting a surrounding explosive atmosphere [12]

o type of protection "op" (optical radiation) - appropriate measures to prevent ignition of an explosive atmosphere by optical radiation [15]

The standards development dynamic is very fast and new editions, incorporating the results of the newest research, are adopted at very close time intervals (few years). This is the reason why the explosion protection standards, regarding the construction of the technical equipment intended for use in explosive areas, overpasses, in some points, the ATEX Directive [16] prescriptions.

Thus, there is a difference between the classification of electrical equipment intended for use in explosive atmospheres according ATEX Directive [16] and the classification of electrical equipment according EN 60079-0 [4]. The ATEX Directive classifies the electric equipments in two groups (as seen previously), but the EN 60079-0 classifies the electric equipments in three groups as follows:

o Group I – electrical equipment intended for use in mines susceptible to firedamp (underground mines susceptible to firedamp);

o Group II – equipment intended for use in places with an explosive gas atmosphere other than mines susceptible to firedamp (chemical and petro-chemical industry, natural gas extraction and processing industry, oil extraction industry, etc.);

o Group III - electrical equipment intended for use in places with an explosive dust atmosphere other than mines susceptible to firedamp.

Our attention will be concentrated on electrical equipment intended for use in explosive gas atmospheres, caused by mixtures of air and gases, vapours or mists.

For group I electrical equipment the maximum surface temperature shall not exceed:

o 150 °C on any surface where coal dust can form a layer,

o 450 °C where coal dust is not likely to form a layer.

Group II is divided in three subgroups:

o IIA – representative gas propane;

o IIB – representative gas ethylene;

o IIC – representative gases hydrogen and acetylene.

This classification is based on the maximum experimental security gap or the minimum ignition current (energy) of the explosive gas atmosphere in which the equipment may be installed.

Also, the maximum surface temperature (on internal or external surfaces of the electrical equipment, depending on the type of protection) needs to be determined. Thus, the electrical equipment of group II is classified according the maximum surface temperature. According this classification, the equipment may have either the maximum determined surface temperature inscribed on its label, or shall bear the marking of the temperature class in which it is included, as follows:

o T1 – maximum surface temperature 450°C
o T2 – maximum surface temperature 300°C
o T3 – maximum surface temperature 200°C
o T4 – maximum surface temperature 135°C
o T5 – maximum surface temperature 100°C
o T6 – maximum surface temperature 85°C

Another classification of electrical equipment is made according the equipment protection level EPL which represents the level of protection assigned to equipment based on its likelihood of becoming a source of ignition and distinguishing the differences between explosive gas atmospheres, explosive dust atmospheres, and the explosive atmospheres in mines susceptible to firedamp.

Group I electrical equipment has been assigned with the following EPL: Ma and Mb (in direct relation with equipment category Ma – M1 and Mb – M2).

Group II electrical equipment for gas atmospheres has been assigned with the following EPL: Ga, Gb and Gc (in direct relation with equipment category Ga – 1G Gb – 2G, Gc – 3G).

Based upon the frequency of the occurrence and duration of an explosive gas atmosphere, hazardous areas in places with an explosive gas atmosphere other than mines susceptible to firedamp (chemical and petro-chemical industry, natural gas extraction and processing industry, oil extraction industry, etc.) are classified into zones [10], as follows:

o - Zone 0 - place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently (ex. inside of a fuel tank between the flammable liquid surface and the top of the tank).

o - Zone 1 - place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally (ex. near the regulating valve of a fuel tank).

o - Zone 2 - place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only (ex. surrounding a sampling valve)

5. GENERAL CRITERIA TO SELECT THE ELECTRICAL EQUIPMENTS INTENDED FOR USE IN EXPLOSIVE ATMOSPHERES

Because the type of protection represents a technical solution, it is very important that it can be associated to electrical equipment without affecting its functional part [2].

There are a lot of types of protection enough various to respond the functional part compatibility requirements for different kind of equipments. This is because not each type of protection can be used for the same electrical equipment and depends on the technical parameters of the equipment.

It shall be remarked that in some cases the electrical equipment must be protected with a pair of compatible redundant types of protection (superimposed).

Supplementary, an electrical equipment can be partially protected or party protected with different types of protection; in this case we have associations of various types of protection. For example a fluorescent luminaire can be constructed by using three types of protection: increased safety for the enclosure and the terminal strip, encapsulation for the electronic ballast and flameproof enclosure for the tube holders [2]. Another example is an electric motor which has the connection box made with the type of protection increased safety and the main compartment of the motor made with the type of protection flameproof enclosure. Also, an electric control button can be conceived using the techniques of two types of protection: flameproof enclosure “d” (for the button itself – the sparking part of the equipment) and increased safety “e” (for the connection terminals of the button).

The correlation between the type of protection and the functional part of the equipment is presented in table 1, and it is derived from the principles of the types of protection [2].

Table 1

Correlation between the type of protection and the functional part of the equipment

Type of protection		**Type of equipment – functional part (examples)**
Symbol	**Name**	
Ex m	Encapsulation	Small circuit parts; small components.
Ex p	Pressurization	Control panels, analyzers, large electric motors, electric heaters
Ex o	Oil immersion	Transformers, starting resistors
Ex e	Increased safety	Electric motors, luminaires, terminal and connection boxes (equipments that do not produce arcs and sparks)
Ex n	Non-incendive	Electric motors, luminaires, terminal and connection boxes
Ex d	Flameproof enclosure	Electric motors, luminaires, terminal and connection boxes, switchgear, control gear, indicating equipment, heating equipment, gas detectors
Ex i	Intrinsic safety	Measurement, monitoring and control systems, sensors, actuators (low current electrical equipment).
Ex q	Powder filling	Transformers, capacitors, ballasts for light fittings
Ex op	Optical radiation	Lamps, lasers, LED’s, optical fibers (equipments for data transmission, measurements, surveillance using optical radiation)

In order to select the appropriate electrical equipment for hazardous areas, the following information is required [3]:

o classification of the hazardous area including the equipment protection level requirements where applicable;

o temperature class or ignition temperature of the gas or vapour involved;

o where applicable, gas or vapour classification in relation to the group or subgroup of the electrical equipment;

o external influences and ambient temperature.

Referring to the hazardous area classification and the equipment protection level EPL, the electrical equipment admitted in hazardous areas is as follows:

o in zone 0 – electrical equipment of EPL Ga;

o in zone 1 – electrical equipment of EPL Ga or Gb;

o in zone 2 - electrical equipment of EPL Ga, Gb or Gc.

For each type of protection there is assigned an EPL. The relationship between the types of protection and the EPL is as presented in Table 2.

Table 2

Correlation between types of protection and EPL

EPL	Type of protection	Symbol	Standard
Ga	Intrinsically safe	„ia”	EN 60079-11
	Encapsulation	„ma”	EN 60079-18
	Two independent types of protection each meeting EPL 'Gb'		EN 60079-26
	Protection of equipment and transmission systems using optical radiation		EN 60079-28
Gb	Flameproof enclosures	„d”	EN 60079-1
	Intrinsically safe	„ib”	EN 60079-11
	Increased safety	„e”	EN 60079-7
	Encapsulation	„m”, „mb”	EN 60079-18
	Oil immersion	„o”	EN 60079-6
	Pressurized enclosure	„p”, „px” or „py”	EN 60079-2
	Powder filling	„q”	EN 60079-5
	Fieldbus intrinsically safe concept (FISCO)		EN 60079-27
	Protection of equipment and transmission systems using optical radiation		EN 60079-28
Gc	Intrinsically safe	“ic”	60079-11
	Encapsulation	“mc”	EN 60079-18
	Non-incendive	“n”, “nA”, “nR”, “nL”, “nC”	EN 60079-15
	Pressurized enclosures	“pz”	EN 60079-2
	Fieldbus non-incendive concept (FNICO)		EN 60079-27
Gc	Protection of equipment and transmission systems using optical radiation		EN 60079-28

Selection according to the ignition temperature of the gas or vapour

The electrical equipment shall be so selected that its maximum surface temperature will not reach the ignition temperature of any gas or vapour which may be present.

Symbols for the temperature classes which may be marked on the electrical equipment have the meaning indicated in table 3.

Table 3

Relationship between gas or vapour ignition temperature and the temperature class of equipment

Temperature class required by the area classification	Ignition temperature of gas or vapour °C	Allowable temperature classes of equipment
T1	>450	T1 – T6
T2	>300	T2 – T6
T3	>200	T3 – T6
T4	>135	T4 – T6
T5	>100	T5 – T6
T6	>85	T6

If the marking of the electrical equipment does not include an ambient temperature range, the equipment shall be used only within the temperature range –20°C to +40°C.

If the marking of the electrical equipment includes an ambient temperature range, the equipment shall only be used within this range.

Selection according to equipment grouping

When selecting electrical apparatus, the grouping of the hazardous substance shall be taken into account as described in table 4.

Table 4

Relationship between gas/vapour subdivision and equipment group

Gas/vapour subdivision	Permitted equipment group
IIA	II, IIA, IIB or IIC
IIB	II, IIB or IIC
IIC	II or IIC

External influences

Electrical equipment shall be selected and installed so that it is protected against external influences (e.g. chemical, mechanical, vibrational, thermal, electrical and humidity) which could adversely affect the explosion protection.

Precautions shall be taken to prevent foreign bodies falling vertically into the ventilation openings of vertical rotating electrical machines.

The integrity of electrical equipment may be affected if it is operated under temperature or pressure conditions outside those for which the equipment has been constructed. In these circumstances, further advice should be sought.

5. CONCLUSIONS

✓ This paper can be used as a guide for selecting the electrical equipments for use in areas classified as with hazard of explosive atmospheres

✓ In order to design electrical equipment intended for use in areas classified as with hazard of explosive atmospheres, more types of protection might be necessary to be used.

✓ For selecting the electrical apparatus for use in explosive gas atmospheres, the user should consider:

- ✓ the area in which the apparatus will operate;
- ✓ type of protection shall be suitable for the considered area;
- ✓ correct association of apparatus with processes;
- ✓ certification according to ATEX Directive 94/9/EC.

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