Practical aspects regarding the evaluation of explosion protected equipment

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Abstract. Based on the experience accumulated over time on the evaluation of equipment and installations in environments with potentially explosive atmospheres, this paper is intended to be an element of synthesis on issues related to the "in situ" assessment and solutions of solvency the deficiencies found. The assessment of these installations is very important in order to verify the implementation of measures that lead to minimizing the risk of ignition of explosive atmospheres. Evaluation of these installations is made through an on-site visit and on the basis of the technical documentation developed by the care of the user.
In first part of the paper were presented the legal aspects regarding the placing on the market and the use of equipment designed for potentially explosive atmospheres.
The paper is continuing with the presenting the technical aspects regarding the evaluation of equipment and installations operating in potentially explosive atmospheres followed by requirements for electrical equipment.
The main conclusion, of the paper is that the explosion protection of the equipment intended for use in potentially explosive atmospheres may be invalidated by the incorrect selection of the equipment, incorrect installation of the product, inadequate: performance of inspection operations, maintenance or repairing of equipment.

1 Introduction

Installations where flammable materials are handled or stored must be designed, operated and maintained in such a way that all releases of flammable materials, and consequently the extent of hazardous areas, are kept to a minimum, in terms of frequency, duration and quantity, whether or not operation is normal [1].

An area where explosive atmospheres may occur in such high concentrations as to require special precautions to protect the health and safety of the workers involved is considered dangerous. Explosive atmosphere is defined as a mixture with air, under atmospheric conditions, of a flammable material mixed with air in which, after ignition, the combustion propagates throughout the whole unconsumed mixture [2, 3]. In situations where an explosive atmosphere may occur, the following measures should be provided [4]:

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- eliminate the probability of an explosive atmosphere occurring near the ignition source, or
- eliminate sources of ignition.

If these measures cannot be applied, preventive measures must be chosen and applied, so that the probability of the simultaneous occurrence of the two elements listed above is brought to a sufficiently low level to be accepted.

For an explosive atmosphere to exist, the flammable substance must be present in certain concentrations. If the concentration is too low (poor mixture) or too high (rich mixture) no explosion can occur, in fact a weak combustion reaction may occur but not a reaction in the whole mixture. Thus, the explosion can occur only in the presence of an ignition source and when the concentration is in the explosive range of the substance, respectively between the lower flammability limit (LFL) and the upper flammability limit (UFL). Explosive limits depend on pressure and the percentage of oxygen in the air.

2 Legal aspects regarding the placing on the market and the use of equipment designed for potentially explosive atmospheres

In the field of Ex protection there are two European Directives, called ATEX Directives and their acronym comes from "ATmosphere EXplosive". These regulate the placing on the European market of products intended for use in potentially explosive atmospheres and respectively their safe use [5, 6], as follows:

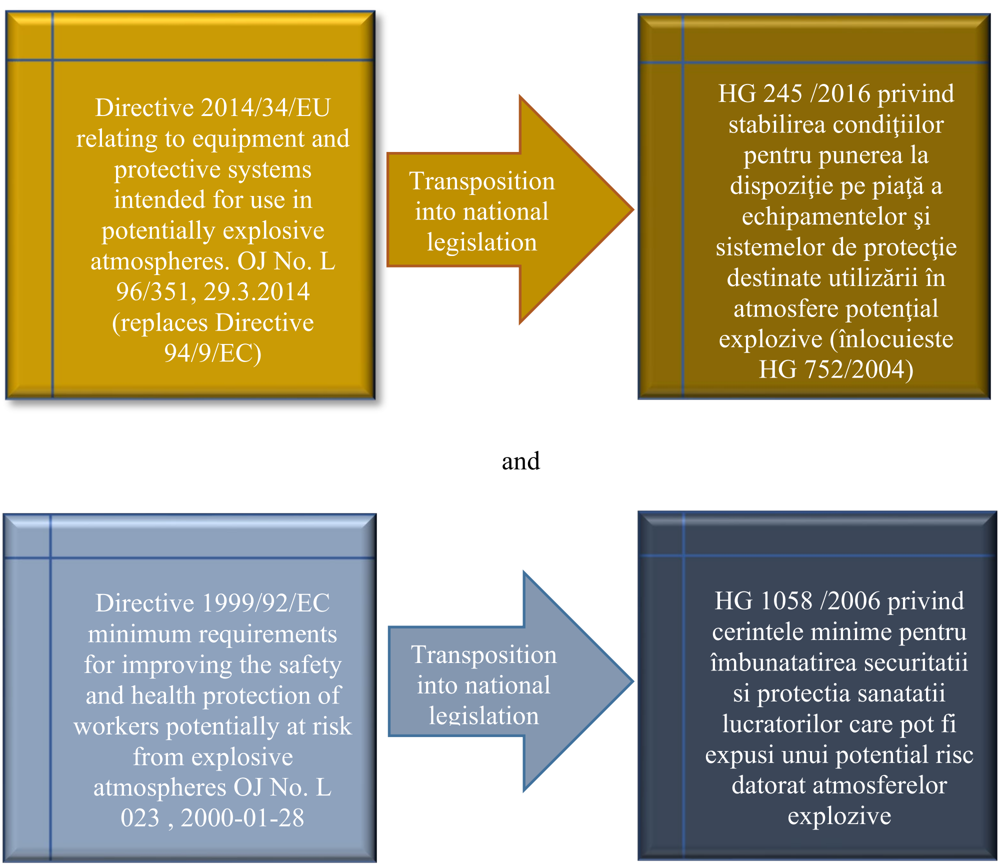

Fig. 1. Correspondence between EU and national legislation

Equipment according the ATEX Directive are classified into groups and categories, and the new standards in the field introduced the term Equipment Protection Level (EPL). According to EPL classification Ga, Gb, Gc are used for equipment intended for use in potentially explosive atmospheres caused by gases and Da, Db, Dc for equipment intended for use in potentially explosive atmospheres generated by combustible dusts in air. But currently there is a difference between classification found in the ATEX Directive and technical standards, as shown in Table 1. In the near future these discrepancies will have to be resolved in order to exclude the possible misleading interpretation for end users.

Table 1. Classification of ATEX equipment by groups and categories.

ATEX DIRECTIVE		New tehnical standards (EN 60079, EN 80079 series)	
Group	**Equipment Category**	**Group**	**Equipment Protection Level (EPL)**
Group I mining	M1	Group I mining	Ma
	M2		Mb
Group II Gases and Dusts	1G	Group II Gases	Ga
	2G		Gb
	3G		Gc
	1D	Group III Dusts and Fibers	Da
	2D		Db
	3D		Dc

Hazardous areas are classified into zones [2, 3] according to the frequency of occurrence and duration of the presence of explosive gas or explosive dust atmospheres generated as follows:

Zone 0 (gases) or 20 (dusts): Area where the explosive atmosphere is present permanently, or for long periods of time.

Zona 1 (gases) or 21 (dusts): Area in which the explosive atmosphere is likely to occur in normal operation.

Zona 2 (gases) or 22 (dusts): Area in which an explosive atmosphere is not likely to occur during normal operation and in which, if it does occur, it is likely to occur only rarely and only for a short period of time.

Combustible dust is defined as small solid particles with a nominal size of 500 µm or less, which may be found suspended in air or deposit under their own weight, and may form explosive mixtures with air at atmospheric pressure and normal temperatures. As there is no exact rule regarding the definition of the presence of explosive atmosphere (duration and probability) in relation to the areas classified Ex, Zone 0, 1, 2 or Zone 20, 21, 22, the data in table 2 can be considered as reference.

Table 2. Probability and duration of presence the explosive atmosphere.

Hazardous area classification (Zone)	Probability, P [$year^{-1}$]	Duration, t [hour/year]
0 or 20	$P > 10^{-1}$	> 1000 h / year
1 or 21	$10^{-1} > P > 10^{-3}$	10 ÷ 1000 h / year
2 or 22	$10^{-3} > P > 10^{-5}$	< 10 h / year

Hazardous area classification is a method of analysis and classification of the environment in which gaseous explosive atmospheres may occur or due to the presence of dust, so as to facilitate the correct choice and installation of usable equipment without generating a hazard in this environment, taking into account the groups of gases and gas temperature classes and the ignition temperature of the dust layer or cloud.

In practice, in most cases where flammable substances are used, it is difficult to guarantee that an explosive atmosphere will never occur. It can also be difficult to guarantee that electrical equipment will never generate a source of ignition. Therefore, when the presence of an explosive atmosphere is very likely, the use of electrical equipment with a low probability of generating a source of ignition will be used. On the contrary, if the probability of the presence of a gaseous atmosphere is low, it will be possible to use electrical equipment built according to less stringent requirements.

Starting from the explosion protection principles stated above, in Table 3 are summarized the requirements for technical equipment, depending on the intended use.

Table 3. Requirements for technical equipment depending on the intended use.

ZONE	The presence of the explosive atmosphere	Avoiding sources of ignition	Required level of protection	Group II, Category	EPL
2 or 22	Unlikely or only for a short period of time	During normal operation	NORMAL	3G / 3D	Gc / Dc
1 or 21	Likely to occur	Also, during predictable failures (one defect)	HIGH	2G / 2D	Gb / Db
0 or 20	Continuous, frequent or for long periods	Also, during rare failures (two independent faults)	VERY HIGH	1G / 1D	Ga / Da
Requirements for users		Requirements for manufacturers			
Directive 1999/92/EC (HG 1058/2006)		Directive 2014/34/EU (HG 245/2016)			

3 Technical aspects regarding the evaluation of equipment and installations operating in potentially explosive atmospheres

Any product designed for use in potentially explosive atmospheres placed on the market after the conformity assessment procedures of the ATEX Directive [5, 6] were applied, the explosion protection characteristics can be altered due to multiple factors:

- an incorrect selection of the equipment according to the final destination
- an incorrect design of the installation in which the product is going to be incorporated;
- inadequate performance of inspection operations and maintenance of equipment
- modifications made to the certified Ex equipment
- inadequate repairs applied to the certified Ex equipment

For the above-mentioned operations that can compromise the explosion protection characteristics, only the manufacturer instructions and the requirements of the ATEX Directive are not enough. In these conditions the member states adopted their own legislation regarding those issues. In that, in Romania, in 2007, after the adhesion to the EU, the normative document [7] was adopted. According of this normative at commissioning of a technical installation operating in potentially explosive atmospheres a verification of the technical documentation and an on-site assessment must be performed. This is to assess the technical installation in order to check if all the measures required to ensure the protection to explosion are adopted, especially those regarding the equipment/protective systems used in Ex classified areas.

Technical documentation of the installation shall comprise at least:

- a general presentation of the installation;
- technical drawings and diagrams showing the operation of the technical system components;
- list of technical system components, with their rated parameters (including their Ex-characteristics);
- zoning plan of Ex hazardous areas;
- inspection schedule.

4 Requirements for electrical equipment

Electrical equipment for potentially explosive atmospheres must comply with the requirements of the general specific standard [1] and the standards specific to the type or types of protection that formed the basis for the construction of that device. Types of protection for electrical equipment intended for use in explosive atmospheres generated by gases, vapors, flammable mists or dusts can be grouped into three categories, depending on the presence of the ignition source and the potentially explosive atmosphere:

1 - types of protection that allow direct contact between the ignition source and the hazardous atmosphere (flameproof enclosure “d”, intrinsic safety “i”, non-incendive “nC”).

2 - types of protection that do not allow direct contact between the ignition source and the hazardous atmosphere (oil immersion ”o”; pressurized enclosure ”p”, powder filling ”q”, encapsulation “m”).

3 - types of protection which by construction try to eliminate the ignition source under specified conditions (increased safety "e", non-incendive "nA").

This classification is in fact, a ranking of the level of security offered by each type of protection. The highest level of security is provided by the types of protection from point 1, and the lowest level, from those from point 3. In order to choose the type or types of protection of the explosion-proof electrical equipment, an analysis is made regarding the explosive atmospheres in which the electrical equipment operates, determining:

- explosive properties;
- their nature;
- frequency of occurrence.

Thus, in order to correctly select the electrical equipment for Ex hazardous areas, the following information is required [1, 8]:

- classification of Ex hazardous area;
- classification of gases and vapors in relation to the group/subgroup of electrical equipment;
- the temperature class or the ignition temperature of the gases or dusts which create the explosive mixture;
- external influences and ambient temperature.

The assessment of technical installations operating in potentially explosive atmospheres is of high importance considering the existing explosion risk which has to be minimized in order to ensure people's health and safety, as well as to prevent goods damage and protection of the environment. In order to perform the assessment of technical installations both the documentation and the installation and equipment that is included in the installation must be verified by competent personnel [8]. The assessment applies to all installations operating in potentially explosive atmospheres for example: installations for oil and gas extraction, transport, storage and processing, gas stations, wood processing industry, mills, etc.)

When performing the assessment, the provisions of applicable standards [8, 9, 10] and regulations in force are used. During the assessment, non-conformities can occur, and these are brought in attention to the user of the installation, in order to adopt the required measures to deal with the non-conformities. A lot of non-conformities occur due to the lack of training for the personnel performing the installation/maintenance of technical equipment . Some common issues that were found during the assessment are:

1. Location of electrical equipment in normal construction in Ex classified areas.

Fig. 1. Example of non-Ex equipment found in Ex classified areas, during site assessment visit.

2. Incorrect installation of electrical equipment in Ex construction.

Fig. 2. Example of incorrect installation of electrical equipment in Ex construction.

3. ATEX certified Ex equipment is used in Ex areas, but the equipment is not selected according the gas group specifications and/or dust auto-ignition temperature (i.e. the area requires IIC equipment but the equipment installed in the field is marked IIB or IIA [6, 9, 11];
4. Modifications to the certified Ex equipment that compromise the Ex certifications and invalidate the protection to explosion (modifications to the components of the equipment) [13, 14].

Fig. 3. Example of the improper choosing cable entry at the flame-proof equipment.

5. Invalidation of Ex protection types, through incorrect maintenance works applied to Ex construction equipment [12].

Fig. 4. Example of improper maintenance work applied to Ex equipment.

6. Lack of mandatory maintenance operations on Ex equipment which work in Ex classified environments.

Fig. 5. Example of mandatory failure maintenance works.

7. Non-compliance with electrical separation requirements and insulation distances between circuits with intrinsic safety “i” and those without intrinsic safety (eg. the distance between the conductors at the entrance and exit of an intrinsic safety barrier, the equipment must be securely fastened, etc.) [13].

Fig. 6. Non-compliance with electrical isolation and distances providing electrical insulation between intrinsic safety circuits.

8. Failure to comply with the interconnection of equipment with the type of protection intrinsic safety "i".

When it is necessary to install an equipment (eg. a sensor) having as type of protection intrinsic safety "i", when choosing the safety barrier must take into account the electrical parameters of the electrical circuit, being mandatory the simultaneous fulfillment of the following conditions [13, 15]:

a) for the electrical parameters of the intrinsically safe sensor and the safety barrier in the circuit to be fulfilled the condition:

$$U_o, I_o, P_o \leq U_i, I_i, P_i \quad \text{and} \tag{1}$$

$$C_o, L_o \geq C_i, L_i \tag{2}$$

and if applicable, check the permissible Lo / Ro ratio where:
- $U_o, I_o, R_o, P_o, C_o, L_o$ the output parameters of the intrinsic safety barrier
- U_i, I_i, P_i, C_i, L_i input parameters for the Ex “i” sensor

b) the maximum permissible cable length imposed to the capacitance limitation:

$$L_C = \frac{C_0 - \sum C_i}{C_{cable-specific}} \; [m] \tag{3}$$

$$L_L = \frac{L_0 - \sum L_i}{L_{cable-specific}} \; [m] \tag{4}$$

Of the two resulting lengths, the smallest element obtained between the LC and LL cable length shall be taken into account.

5 Conclusions

Even if a product designed for use in potentially explosive atmospheres is placed on the market after the conformity assessment procedures of the ATEX Directive 2014/34/EU were applied, the explosion protection characteristics can be altered due to multiple factors such as: incorrect selection of the equipment, incorrect installation of the product, inadequate performance of inspection operations, inadequate maintenance of equipment, inadequate overhaul or repairing of equipment.

In Romania, in 2007, after the adhesion of Romania to the EU member countries, the normative document NEx 01-06/2007 was adopted. At commissioning of a technical installation operating in potentially explosive atmospheres a verification of the technical documentation and an on-site assessment must be performed by INSEMEX Petrosani. This is to assess the technical installation in order to check if all the measures required to ensure the protection to explosion are adopted, especially those regarding the equipment/protective systems used in Ex classified areas.

Some examples of non-conformities identified during the assessment were shown in this paper. Also, information was presented regarding how to improve the activities: design, mounting, inspection, maintenance, carried out in relation to installations operating in potentially explosive atmospheres in order to preserve explosion protection characteristics for ATEx dedicated equipment.

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