ASPECTS REGARDING THE USAGE OF APPROPRIATE ELECTRICAL EQUIPMENT IN POTENTIALLY EXPLOSIVE ATMOSPHERES GENERATED BY HYDROGEN

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Abstract: Evaluation of explosion-proof protected electrical equipment in scope of certification is extremely important considering the risk of explosion that has to be minimized in order to ensure life safety and health of workers and to prevent damaging of property and the environment, as well as free movement of goods when they meet the essential safety requirements at European level.

Electrical equipment that operates in potentially explosive atmosphere, have characteristics specially designed for operation in this area. For security reasons, it is essential that the integrity of these special features be preserved in these areas throughout the life of the installation.

Using electric equipment in potentially explosive atmospheres brings forward several particularities therefore the problems that appear during the design, construction and operation of electrical devices and installations brings forward numerous difficulties, their approach requiring special attention considering all the technical, economical and labor safety aspects.

The purpose of the paper is to reveal the importance of using appropriate electrical equipment design to be used in potentially explosive atmospheres generated by hydrogen.

Key words: electric equipment, explosive atmosphere, hydrogen.

1. INTRODUCTION

The use, production, processing and storage of petroleum products and gases generate hazardous atmospheres that can be ignited and generate explosions, causing serious damage both to materials and the environment, and especially to human health and integrity. The use of equipment in this environment requires compliance with

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certain well-defined parameters, which must be chosen in correlation with the potentially explosive atmosphere in which it is to be installed and the type of protection, temperature class and category of equipment [3], [6].

The risk of explosion may appear in all the fields of activity in which flammable substances are involved, such as gases, vapours, dusts, mists, which mixed with air may result in potentially explosive atmospheres [6], [2].

In order to increase the occupational health and safety level in potentially explosive atmospheres generated by flammable gases or explosive dusts we have to prevent the ignition of explosive atmospheres. In order to do this the electrical equipment used in such areas must be made with different types of protection so that it can not ignite the explosive mixture surrounding it [2], [11].

The type of protection means the specific measures applied to electrical equipment to avoid ignition of a surrounding explosive atmosphere [1], [12].

2. POTENTIALLY EXPLOSIVE ATMOSPHERES

Explosive atmospheres are defined as a mixture with air, under atmospheric conditions, of flammable substances in the form of flammable gases, mist vapors or combustible dusts, in which, after ignition, combustion is spread throughout the unburned mixture. To generate an explosive atmosphere, the flammable substance must be present in certain concentrations, between the Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL). Explosion limits of the substance may depend on pressure, oxygen concentration in the air and temperature. The mechanism of an explosion generated by a mixture of flammable gas, vapor or mist with air can be expressed by the well-known explosion triangle shown in Figure 1. Thus, the occurrence of an explosion is conditioned by the simultaneous presence of the following three factors:

1. fuel (flammable gases, vapours, mists);
2. oxygen (oxygen, oxidizing substances);
3. efficient ignition source for ensuring the activation of molecules in order to ignite and propagate the fast combustion reaction [4], [13].

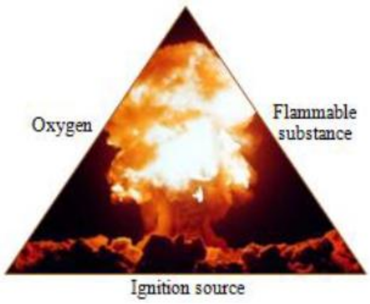

Fig.1. The explosion triangle

Ignition sources can be hot surfaces, sparks, short circuit, static energy, electric arcs, etc.

Directive 2014/34/EU defines several types of groups and categories of electrical equipment (EU Directive, 2014):

Equipment Group I: equipment used for underground mines and for parts of the installations located at the surface of these mines, susceptible to firedamp and/or combustible powders.

Equipment Group II: equipment intended to be used in explosive atmospheres, other than the ones in Group I.

New standards in the field divided Group II of non-mining equipment into Group II for gases, vapours and mists and Group III for flammable powders in air. These standards have also introduced the EPL (Equipment Protection Level) concept: Ga, Gb, Gc for gases and Da, Db, Dc for equipment intended to be used in potentially explosive atmospheres generated by flammable dusts in air, equivalent to categories 0,1,2.

Therefore, a new classification in groups and categories arises:

Gr I mining

Gr II (A, B, C) surface gases

Gr III (A, B, C) dusts

Table. 1. ***Correlation between the equipment category, the equipment EPL and corresponding area***

EPL	**Equipment group**	**Equipment Category (ATEX)**	**Zone**
Ga	II	1G	0
Gb		2G	1
Gc		3G	2

The ignition temperature of potentially explosive substances is another very important aspect in the choice of equipment in the installation. The temperature classes for equipment (maximum temperature), given in table 2, a must be below the ignition temperature of the substance in which it operates [3], [10].

Table. 2. ***The relationship between the gas or vapor ignition temperature and the temperature class of the equipment***

Temperature class required by zone classification	**Ignition temperature of gas or vapor (°C)**	**Allowed temperature classes for the equipment**
T1	450	T1 – T6
T2	300	T2 – T6
T3	200	T3 – T6
T4	135	T4 – T6
T5	100	T5 – T6
T6	85	T6

3. ELECTRICAL EQUIPMENT IN POTENTIALLY EXPLOSIVE ATMOSPHERES GENERATED BY HYDROGEN

Like any flammable fuel, hydrogen can combust. But hydrogen’s buoyancy, diffusivity and small molecular size make it difficult to contain and create a combustible situation. In order for a hydrogen fire to occur, an adequate concentration of hydrogen, the presence of an ignition source and the right amount of oxidizer (like oxygen) must be present at the same time. Hydrogen has a wide flammability range (4-74% in air) and the energy required to ignite hydrogen (0.02mJ) can be very low. However, at low concentrations (below 10%) the energy required to ignite hydrogen is high--similar to the energy required to ignite natural gas and gasoline in their respective flammability ranges--making hydrogen realistically more difficult to ignite near the lower flammability limit. On the other hand, if conditions exist where the hydrogen concentration increased toward the stoichiometric (most easily ignited) mixture of 29% hydrogen (in air), the ignition energy drops to about one fifteenth of that required to ignite natural gas (or one tenth for gasoline) [4], [7].

Hydrogen is a gas of the IIC group and belongs to the temperature class T1, which makes it one of the hottest and most dangerous gases.

The most used electrical equipment in potentially explosive atmosphere is made with type of protection flameproof enclosure and type of protection increased safety [1], [14].

Flameproof enclosure “d”, is an enclosure in which the parts which can ignite an explosive gas atmosphere are placed and 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 gas atmosphere surrounding the enclosure. In case of increased safety concept additional measures are applied to increase the level of safety, thus preventing the possibility of high temperatures and the occurrence of sparks or electric arcs within the enclosure or on exposed parts of electrical equipment [5], [8].

According to specific standards for electrical equipment with flameproof enclosure type of protection, for each group of explosion there is minimum width of joint and maximum gap for enclosures as shown in table 3 ant table 4.

Table. 3. ***Minimum width of joint and maximum gap for enclosures of Groups I, IIA and IIB***

Type of joint		Minimum width of joint L mm	Maximum gap mm														
			For a volume cm³ $V \le 100$			For a volume cm³ $100 < V \le 500$			For a volume cm³ $500 < V \le 2\,000$			For a volume cm³ $2\,000 < V \le 5\,750$			For a volume cm³ $V > 5\,750$		
			I	IIA	IIB	I	IIA	IIB	I	IIA	IIB	I	IIA	IIB	I	IIA	IIB
Flanged, cylindrical or spigot joints		6	0,30	0,30	0,20	–	–	–	–	–	–	–	–	–	–	–	–
		9,5	0,35	0,30	0,20	0,35	0,30	0,20	0,08	0,08	0,08	–	0,08	0,08	–	0,08	–
		12,5	0,40	0,30	0,20	0,40	0,30	0,20	0,40	0,30	0,20	0,40	0,20	0,15	0,40	0,20	0,15
		25	0,50	0,40	0,20	0,50	0,40	0,20	0,50	0,40	0,20	0,50	0,40	0,20	0,50	0,40	0,20
Cylindrical joints for shaft glands of rotating electrical machines with:	Sleeve bearings	6	0,30	0,30	0,20	–	–	–	–	–	–	–	–	–	–	–	–
		9,5	0,35	0,30	0,20	0,35	0,30	0,20	–	–	–	–	–	–	–	–	–
		12,5	0,40	0,35	0,25	0,40	0,30	0,20	0,40	0,30	0,20	0,40	0,20	–	0,40	0,20	–
		25	0,50	0,40	0,30	0,50	0,40	0,25	0,50	0,40	0,25	0,50	0,40	0,20	0,50	0,40	0,20
		40	0,60	0,50	0,40	0,60	0,50	0,30	0,60	0,50	0,30	0,60	0,50	0,25	0,60	0,50	0,25
	Rolling-element bearings	6	0,45	0,45	0,30	–	–	–	–	–	–	–	–	–	–	–	–
		9,5	0,50	0,45	0,35	0,50	0,40	0,25	–	–	–	–	–	–	–	–	–
		12,5	0,60	0,50	0,40	0,60	0,45	0,30	0,60	0,45	0,30	0,60	0,30	0,20	0,60	0,30	0,20
		25	0,75	0,60	0,45	0,75	0,60	0,40	0,75	0,60	0,40	0,75	0,60	0,30	0,75	0,60	0,30
		40	0,80	0,75	0,60	0,80	0,75	0,45	0,80	0,75	0,45	0,80	0,75	0,40	0,80	0,75	0,40

Table. 4. ***Minimum width of joint and maximum gap for Group IIC enclosures***

Type of joint		Minimum width of joint L mm	Maximum gap mm			
			For a volume cm³ $V \leq 100$	For a volume cm³ $100 < V \leq 500$	For a volume cm³ $500 < V \leq 2\,000$	For a volume cm³ $V > 2\,000$
Flanged joints[a]		6	0,10	–	–	–
		9,5	0,10	0,10	–	–
		15,8	0,10	0,10	0,04	–
		25	0,10	0,10	0,04	0,04
Spigot joints (Figure 2a)	$c \geq 6$ mm	12,5	0,15	0,15	0,15	–
	$d \geq 0{,}5\,L$	25	0,18[b]	0,18[b]	0,18[b]	0,18[b]
	$L = c + d$	40	0,20[c]	0,20[c]	0,20[c]	0,20[c]
	$f \leq 1$ mm					
Cylindrical joints Spigot joints (Figure 2b)		6	0,10	–	–	–
		9,5	0,10	0,10	–	–
		12,5	0,15	0,15	0,15	–
		25	0,15	0,15	0,15	0,15
		40	0,20	0,20	0,20	0,20
Cylindrical joints for shaft glands of rotating electrical machines with rolling element bearings		6	0,15	–	–	–
		9,5	0,15	0,15	–	–
		12,5	0,25	0,25	0,25	–
		25	0,25	0,25	0,25	0,25
		40	0,30	0,30	0,30	0,30

4. CONCLUSIONS

The process of selecting electrical equipment for use in areas with potentially explosive atmospheres, generated by mixtures of air and oil, flammable gases or vapours, requires in-depth knowledge in this field.

This paper aims to increase safety in the choice of equipment used in potentially explosive environments, helping users who have no knowledge in this field but are determining factors in their purchase or use.

Hydrogen mixed with air gives rise to one of the most dangerous explosive mixtures, because it has a very low ignition energy and a very high explosion pressure. At the global level, there is a great emphasis on the use of hydrogen as a fuel, both in the automotive industry and in other industries, and that is why it is important that the users of electrical installations that produce, store and use hydrogen, know very well the dangers generated by this gas.

Electrical equipment that operates in potentially explosive environments generated by hydrogen must be certified to be used in potentially explosive atmospheres included in subgroup IIC of gases or be certified for subgroup IIB+H2. If the equipment is included in other gas subgroups, they cannot be used in potentially explosive atmospheres generated by hydrogen.

For the proper functioning of electrical equipment used in potentially explosive atmosphere, the inspection, maintenance and proper repair of these is of great importance. These things must be done by personnel who know the principles of the types of protection, and also to have the necessary infrastructure for a proper repair.

This process takes time and to increase its quality and to facilitate the correct selection of electrical equipment intended for use in such atmospheres, an application has been developed to be a useful tool for personnel working in the industries that process, store or carries flammable substances.

The application presented in the paper provides technical staff with an easy-to-use, intuitive, fast and reliable tool for selecting explosion-proof electrical equipment. The equipment is selected in accordance with the safety and explosion protection in force and brings with it an increase in the level of health and safety at work in industries with potentially explosive atmospheres.

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