Considerations regarding Ex d IIB + H2 method of protection for flameproof electrical equipment

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Abstract. The flameproof enclosure type of protection is still one of the safest because it is based on a very simple and, therefore, unlikely fallible technology. If an explosive atmosphere penetrates an enclosure producing a trigger, the explosion occurs, but it remains confined within the enclosure. Engineers settled the concept that, for IIC areas, have to be necessarily used equipment with cylindrical flame paths, which usually feature a round-shape body that make more complicated the construction of panel boards. EN 60079-1 standard, states that flanged flame paths are allowed in the presence of hydrogen, therefore, in recent years, started the production of "Ex d" explosion-proof enclosures which are usable, as well as with gases of Group IIB, even in the presence of hydrogen. This means that the equipment can be used in an environment containing explosive atmosphere with hydrogen. Acetylene is, therefore excluded, but it has to be considered that the environments with the presence of hydrogen are much more frequent than those with acetylene. The purpose of this paper is to assist manufacturers design flameproof equipment that satisfies the requirements of the standard for group IIB and hydrogen applications in order to smooth the path for certification.

1. Introduction

Flameproof enclosure type of protection is the oldest method of protection that exists [1], [2, 3, 5], the first used and still one of the safest because it is based on a very simple technology and, therefore, hardly fallible.

This method, designed for protection in systems where may be an explosive atmosphere in form of gas, is based on the assumption that it is impossible to prevent a gas to penetrate everywhere. No gasket will ever be able to prevent the entry of a gas in an enclosure. Therefore, if an explosive atmosphere penetrates into an enclosure (such as a junction box, for example) producing a trigger, for example a spark between two electrical contacts, the explosion occurs, but it remains confined within the enclosure, not allowing the spread of flame to the surrounding atmosphere, thus causing a devastating explosion [3-5].

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To ensure this, enclosures must be constructed with a mechanical strength such as to contain the over pressure caused by the explosion and to allow the escape of the burned gases [4, 5].

This is the mission of the flame path which is the interface between two parts of an enclosure, for example the body and the lid. It allows the gases to exit the enclosure and to cool down during the passage, so that they are no longer able to trigger the outside atmosphere [5]. For this reason, the flame path must be sufficiently long and with an interstice enough narrow to guarantee the cooling of the flue gases. There are, depending on the gas and the enclosure volume, precise rules to be observed, which are specified in EN 60079-1 standard [4, 5].

2. Theoretical considerations

Although how to comply with the requirements of the standard, in order to design a flameproof encosure may be more complicated, the way in which the flameproof type of protection works remains simple [3-5]:

1. The flameproof enclosure may contain items that arc, spark or have hot surfaces, which will always present an ignition risk when a gas or vapour/air mixture gets inside.

2. The enclosure must be sufficiently strong to contain the explosion, when it occurs – typically resisting pressures between 6 and 10 bar without bursting (although some equipment may see significantly higher pressures and be designed with greater strength) [7,8].

3. The products of combustion (hot gasses) must vent from the enclosure in such a way that they will not ignite an external explosive atmosphere [5].

4. The temperature on the external surface of the enclosure must not be high enough to ignite an external gas or vapour/air mixture through “hot surface” ignition [4,5].

It is reasonably easy to understand that rapidly burning a gas or vapour in air will result in hot gasses. The actual temperature will depend on the particular mixture of gas or vapour with air. The concepts of richness and leanness apply equally to explosions as to the combustion of petrol in a car engine, with the maximum energy output relating to the “most explosive” mixture. As the exploding gasses are confined in a fixed volume, we can easily predict, for simple situations, the peak pressure [5, 10, 11].

The applicable equation is the Universal Gas Law:

$$(P \cdot V) / T = Constant \tag{1}$$

where P – gas pressure, V – gas volume, T – gas temperature

If V is constant, the pressure is directly proportional to absolute temperature. For most gasses this gives a peak pressure between 5 bar and 8 bar, in a simple enclosure. Unfortunately, not many enclosures are simple. They may be large, of unequal dimension and almost certainly have internal contents that determine how the explosion develops. For this reason, it is not usually possible to calculate pressures, but they are always determined by an actual explosion test. For complex constructions, such as electric motors, the pressures can rise rapidly and pressures in excess of 30 bar have been routinely observed [7, 8, 10, 11].

Immediately after the peak explosion pressure, we have the hottest gasses at the highest pressure, trying to escape from the enclosure [11]. For the flameproof form of protection, it is accepted that the gasses will escape. After all, we have assumed that gasses can get in, so the enclosure is definitely not sealed.

There are several different types of “flamepath” or “gap” in a typical enclosure. The simplest to understand is the plain flange gap. If the gap is wide enough, the flame will exit the enclosure and would ignite any external gas or vapour/air mixture. If the gap is narrow, and of sufficient length, the residual flame or hot gasses, leaving the gap, will not ignite the external mixture. There are three contributory factors [11]:

1. The pressure drop through the gap will cool the exiting gasses. This is exactly according to the Universal Gas Law. We are reasonably familiar with the fact that pumping a bicycle tyre raises temperature and letting air out through the valve cools the air coming out. In some types of construction, this effect alone is sufficient, but in the case of the plain flange gap we rely on at least one other effect.

2. The exiting flame is in the form of a linear jet. This rapidly moving flame acts to create a low pressure zone that “sucks” the cold external atmosphere into the residual flame in a way that “snuffs it out”. This speed/pressure relationship was first described by Bernoulli and leads to the conventional design of an aircraft wing, where the top surface of the wing is longer than the under surface, so that the relative speed of the air on top is higher than the relative speed of the air below and there is an upward pressure. A similar effect is observed at the venturi in a Bunsen burner, where the rapid movement of the gas sucks the air in through the air hole.

3. Transfer of heat energy to the surfaces of the gap does occur, but it plays a very minor part compared to the other two mechanisms. There is a trade-off between gap length and gap width, with the longer the gap length, the wider the permitted gap. The permitted gaps also vary with the enclosure volume and for particular gasses, specifically in relation to their flame velocities in free air and the minimum amount of energy required to initiate an ignition process. In order to standardise the gaps, we have four designated gas groups, and each has its own “characteristic gas” used when describing the suitability of a particular enclosure.

Experimental work has also shown the effect of interrupting the flamepath, for example by passing fastening screws between a cover and a lid, across a plain flange gap (Figure 1) [7,8].

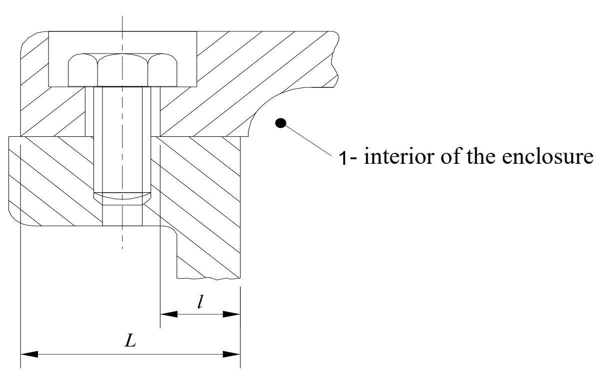

Fig. 1. Plain flange gap interrupted by holes for the passing of fastening screws

The Groups, flame velocity and minimum ignition energy are characterised as follows [5]:

Table 1. Groups, flame velocity and minimum ignition energy

GROUP	Characteristic gas (used for testing)	Flame velocity (m/s)	Minimum ignition energy (micro joules)
I	Methane (representing firedamp in the mining situation)	3.5	525
II A	Propane	4.0	320
II B	Ethylene	6.5	160
II C	Hydrogen	20	40
	Acetylene	14	40

The permitted gaps are designated in the standard and reference should be made to Tables 2 and 3 in standard IEC 60079-1 [5]. Hydrogen and acetylene are both described as the characteristic gasses for Group IIC, as it is necessary to perform some of the tests with both gasses [4,5]. Occasionally, if the enclosure will not pass the tests for acetylene, the equipment may be marked for “IIB + Hydrogen” [5]. Figure 2 shows an example of flameproof enclosure (electrical switch board) for Group II B, with flange joints.

Fig. 2. Example of flameproof enclosure for Group IIB

Although it might be expected that an enclosure designed to meet the gap dimensions given in the standard should pass a transmission test (with the explosive gas mixture both inside and outside the enclosure), this is not always so. At the high pressures achieved inside the enclosure, it cannot be assumed that the designed gap will always be maintained. Even apparently rigid constructions can flex sufficiently for the gap to open under the dynamic pressure, allowing the hot gasses to escape without sufficient cooling, and therefore allowing the external atmosphere to be ignited [10,11].

As part of the testing sequence, the enclosure will have already been stressed by being subjected to a static (hydraulic) pressure which can have permanently opened the gaps a fraction. In the case of plain flanged joints, this problem can often be overcome by adding further securing fasteners. Figure 3 shows the testing chamber used for carrying out tests in explosive mixtures, for flameproof enclosures [7,8].

Fig. 3. Testing chamber for tests in explosive mixtures

3. Regulatory principles

The EN 60079-0 standard, which establishes the general rules for equipment that can be used in environments with a potentially explosive atmosphere, divides the electrical equipment into three groups: Group I; Group II: Group III [1 - 4].

The Group I include equipment that can be used in mines where firedamp gas may be present [4].

The Group III has equipment that can be used in areas with potentially explosive atmospheres for the presence of dust, while those belonging to Group II can be used in places with the presence of an explosive atmosphere due to the presence of surface gases, i.e. different from firedamp [4].

The electrical equipment of Group II are divided in accordance to the explosive atmosphere for the presence of those gases to which they are intended [4].

The division is, also in this case, into three groups:

- II A, a typical gas of this Group is the Propane;
- II B, a typical gas is the Ethylene;
- II C, typical gases are Hydrogen and Acetylene.

This division is based on the maximum experimental safety gap, called MESG: the flame caused by the explosion, which may occur in the event of an accident inside the enclosure, must be cooled down passing, as mentioned above, through the flame path which has different construction methods and length depending on the type of gas [5].

For less dangerous gases, as those of II A and II B Groups, you can use the flat, corner, cylindrical flame path, while for the most dangerous gases, represented by the Group IIC, the flame path can only be cylindrical or threaded, flanged only for very small volumes [5].

Without going into technical design reasons that have led to these choices, we can generalize, without getting wrong, stating that the flame path for Groups II A and II B is flat, while for the II C Group it is cylindrical or threaded [5].

The constructive methodology between the II A and II B is the same, the difference is represented only by the flame path length, greater for the II B Group.

4. Type of flame paths

4.1. Non-threaded flame paths

Within this category there are different types of flame paths. The main ones are cylindrical and plan. The cylindrical flame paths are universal, usable for any type of application and with gas of any group. Normally, they are difficult to find in equipment on the market due to their complexity of production which is reflected in a higher cost. The plan flame paths, on the contrary, are the most common, but they can't be used anywhere; in fact, they are prohibited in applications where there's presence of acetylene (gas group II C) [5].

4.2. Threaded flame paths

They are divided into two groups, cylindrical and tapered. With regards to the cylindrical threaded flame paths you will need to use threads that meet the tolerances of ISO 965-1 standard with a pitch greater than or equal to 0.7 mm. For pitches of more than 2 mm, manufacturers should take necessary measures to ensure that the enclosures pass the test of non-transmission of the flame. Threads must be more than 5 for enclosure with volume up to 100 cm^3 and more than 8 for enclosures with a volume greater than 100 cm^3 [5, 9].

4.3. Flame paths on rotating machines

On 'Ex d' rotating electrical machines, it's necessary to provide a flame path on the propeller shaft. Flame paths positioned in such places must not be subject to wear. They must be completely free and independent from the other structures that support the propeller shaft allowing the rotation. Any bearings, seals, lubrication channels, etc. must be outside of the length of the flame path and it must not be interrupt [5].

4.4. Flame paths on rotating machines

To ensure the safety of an enclosure, it should be checked that the flame paths are not blocked and not closed to solid objects such as pipes, walls, trellises or other enclosures which may obstruct the proper release of flue gases. It's a good practice respect the minimum distances between an enclosure and the surrounding objects as required by EN 60079-14 standard, Paragraph 10.2. [6].

5. Conclusions

The majority of "Ex d" junction boxes is designed and built for II B and II C Groups. The structural differences between the II A and II B are, as we said, very limited and the cost difference, in favour of the II A, is not enough to justify a double production. Therefore, normally, are used II B junction boxes even for the II A. For the II C Group, the flame path cannot be flat for junction boxes with volumes greater than 0.5 liters, but must be cylindrical and, therefore, the construction technology of the II C enclosures must necessarily be different than II B junction boxes.

Very often, the need to manufacture a cylindrical flame path obliges the manufacturer to build round or square-shape enclosures. II B enclosures, normally rectangular-shape, are preferred for the easier realization of switchboards composed of side by side enclosure connected through appropriate sealing fitings.

Over the years, the technicians settled the concept that, for II C areas, have to be necessarily used junction boxes with cylindrical flame path, which usually feature a round-shape body and fixed threaded hubs that make more complicated the construction of panel boards.

This basis is not exact. EN 60079-1 standard, paragraph 5.2.7, states that the flat flanged flame paths are not permitted in the II C Group for volumes greater than 0.5 litres only if the explosive atmosphere is characterized by acetylene. Instead, they are allowed in the presence of hydrogen.

In recent years, therefore, started the production of “Ex d” explosion-proof enclosures which are usable, as well as with gases of II B Group, even in the presence of hydrogen.

It is possible to verify whether this application is suitable by checking the presence on the product catalogue of the marking: Ex d II B + H2.

This means that the junction box can be used in an environment containing explosive atmosphere with hydrogen. Acetylene is, therefore, excluded, but we must consider that the environments with the presence of hydrogen are much more frequent than the environments containing acetylene.

With the method of protection Ex d II B + H2, the junction boxes can be manufactured with flange flame paths and have all the constructional advantages typical of these boxes: as rectangular or square-shaped, they can be easily assembled to make electrical panels.

A factor not negligible, in addition to the ease of assembling of rectangular-shaped enclosures to make electrical panels, is also represented by the cost, which is normally lower for Group II B junction boxes than those for Group II C.

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