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Aspects regarding the influence of internal explosions over the maximum surface temperature for equipment with type of protection flameproof enclosure

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Abstract. The type of protection flameproof enclosure “d” consists in placing the parts that could ignite an explosive atmosphere inside of an enclosure that can withstand the pressure developed during an internal explosion of an explosive mixture and which prevents the explosion transmission to the explosive atmosphere surrounding the enclosure. The protection to explosion must remain valid even in case of an internal explosion. The maximum surface temperature of electrical equipment is defined as the highest temperature which is attained in service under the most adverse conditions (but within the specified tolerances) by any part or surface of equipment. When determining the maximum surface temperature of a flameproof equipment the temperature of external surfaces is considered. The increase of temperature due to an internal explosion is not considered. The purpose of this paper is to highlight this temperature increase during an internal explosion in case of a flameproof enclosure.

1 Introduction

The equipment, components and protective systems used in hazardous explosive atmospheres must fulfil the requirements of ATEX Directive 2014/34/EU (transposed in Romanian legislation by Government Decision no. 245/2016) [1]. Assessment of products (equipment, components and protective systems) falling under the ATEX Directive is made by verification of the technical documentation and specific tests [2].

Requirements of harmonized standards (the SR EN 60079 series) are used to verify the specific characteristics related to explosion protection for electrical equipment [2]. SR EN 60079-0 [3] and other standards from the SR EN 60079 series (that contain specific requirements for the type(s) of protection applied) are used in the assessment process [2].

Flameproof enclosure “d” is a type of protection that consists in placing the parts that could ignite an explosive atmosphere inside of an enclosure that can withstand the pressure

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developed during an internal explosion of an explosive mixture and which prevents the explosion transmission to the explosive atmosphere surrounding the enclosure [4]. Electrical equipment producing electrical arcs and sparks in normal operation are, in general, protected by using this type of protection [2, 4, 5]. There are 3 protection levels in which the equipment with type of protection flameproof enclosure can be included: “da”, “db” or “dc” [4, 6].

Flameproof enclosure electrical equipment, in order to be evaluated from the explosion protection point of view, shall be submitted to type tests. These tests include some specific tests like determination of maximum surface temperature (to include the equipment in a certain temperature class), resistance to impact test, degree of protection test (IP) and, when applicable, also the tests for thermal endurance (heat and cold), resistance to light; and the tests in explosive mixtures (these are considered the most important specific tests performed to verify the explosion protection characteristics for the type of protection “d”) [2, 3, 4].

The following tests in explosive mixtures can be performed, in case of flameproof enclosure level “db” [2], [4]:

1)Determination of explosion pressure (reference pressure);
2)Overpressure test;
3)Test for non-transmission of an internal ignition.

A specific source of ignition for explosive atmospheres is represented by hot surfaces [7]. Thus, the hottest points of equipment that could come in contact with the explosive atmosphere must be identified and the maximum surface temperature has to be determined. The maximum surface temperature of electrical equipment is defined as the highest temperature which is attained in service under the most adverse conditions (but within the specified tolerances) by any part or surface of equipment [3, 8, 9].

Determination of maximum surface temperature is performed under the most adverse ratings with an input voltage of 90 % of the rated voltage or at 110 % of the rated voltage of the electrical equipment (whichever gives the maximum surface temperature) [3, 8]. Where equipment rating is a range (for example, 100 - 250 V; or 240 V± 10%), the test shall be performed at 90 % of the lowest value in the range or at 110 % of the highest value in the range, whichever results in the higher temperature rise [3]. The measured maximum surface temperature shall not exceed, for Group II equipment, the marked temperature or temperature class, less 5 K for temperature classes T6, T5, T4 and T3 (or marked temperatures < 200 °C), and less 10 K for temperature classes T2 and T1 (or marked temperatures > 200 °C) [3, 8].

Knowing that the equipment with type of protection flameproof enclosure “d” must withstand an internal explosion, the maximum surface temperature is determined considering the hottest points, on the external part of the enclosure. Also, supplementary conditions (to those mentioned before), for type of protection “d” must be observed, as given in Table 1:

Table 1. Supplementary conditions for determination of maximum surface temperature [4]

Type of electrical equipment	**Overload or malfunction conditions**
Luminaires (without ballast)	None
Luminaires with electro-magnetic ballasts	Un + 10 % Rectifier effect simulated by diode
Luminaires with electronic ballasts	As specified by the applicable standard for industrial equipment
Motors	None
Resistors	None
Electromagnets	Un and worst-case air-gap
Other equipment	As specified by the applicable standard for industrial equipment

According to the definition of the type of protection flameproof enclosure, the equipment must be safe even in case of an internal explosion [4]. But, the temperature increase in case of an internal explosion is not considered when determining the maximum surface temperature. This paper has the purpose of pointing out the increase of temperature during an internal explosion in case of an Ex d (flameproof enclosure) equipment, influencing also the surface temperature.

2 Testing conditions

In order to point out the increase of temperature during an internal explosion in case of an Ex d (flameproof enclosure) equipment a cylindrical testing sample was used, as presented in Fig. 1. The testing sample was also used in an interlaboratory proficiency scheme to verify some specific characteristics related to flameproof enclosure tests in explosive mixtures [10].

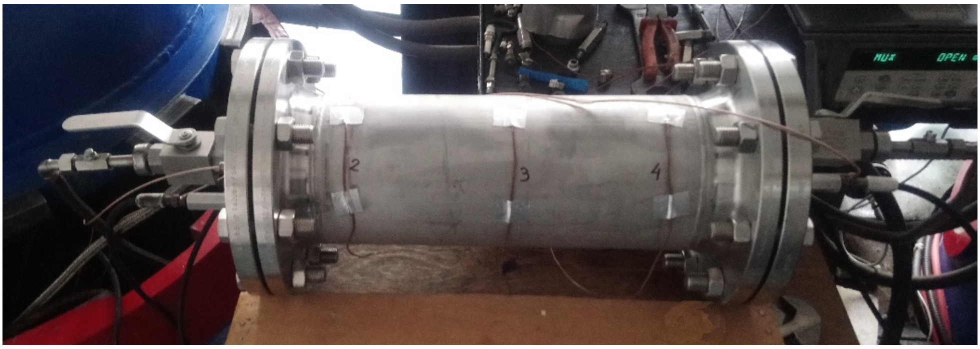

Fig. 1. Test sample

The test sample used is made of stainless-steel grade F304L. It consists of a pipe with 2 welded connection flanges at the ends having a length of 500 mm, an internal diameter of 160 mm and an external diameter of 169 mm (resulting a thickness of 4,5 mm). To close the testing sample two blind closing flanges (22 mm thickness) with connection holes were used, each one of them being fixed to the pipe flanges by 8 locking screws. The sealing between the flanges is provided by the means of 2 flange gaskets (one for each end of the test sample). A gas inlet and a gas outlet are provided at the two side ends of the test sample on the closing flanges, together with two closing manual ball valves. Also, ignition spark plugs are positioned at each of the two closing flanges, connected to high voltage coils.

Five J type thermocouples were placed on the test sample in order to monitor the increase of temperature recorded during an internal ignition of a testing mixture. The thermocouples were placed at approximately equal distances from each other (at approximately 125 mm). Two thermocouples were placed on the closing flanges, one thermocouple at the middle of the test sample and the other two between the middle and each end. One thermocouple was placed so as to monitor the ambient temperature. To monitor the temperature increase during the tests in explosive mixture, the thermocouples were connected to a measuring system consisting of an Agilent 34970A multiplexer and a laptop using an adequate software to monitor the temperature increase (Benchlink Data Logger). The schematic mounting arrangement of the test sample is represented in Figure 2.

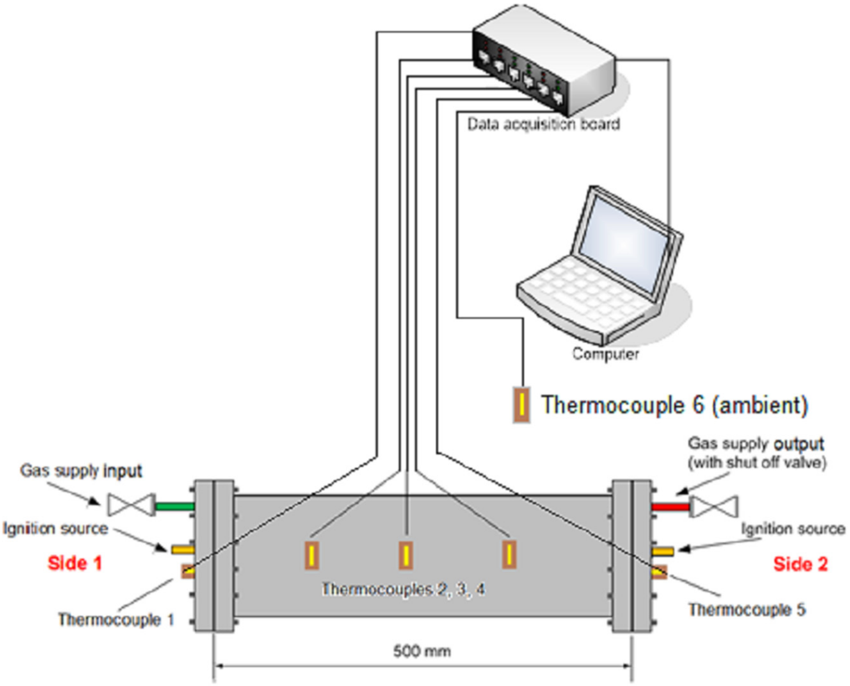

Fig. 2 Schematic of test sample and connections

These are controlled through the test rig used to perform the tests in explosive mixtures. The test rig is used to prepare the gaseous explosive testing mixtures, to monitor the test parameters (pressure, concentration, humidity, temperature, explosion pressure, point of ignition, point of maximum pressure etc.) and to generate the results for the test report. In the structure of the test rig in explosive mixtures are included: explosion chamber, devices for lifting the cover of the explosion chamber, electric hoist (for handling heavy test objects), explosive test installation, paramagnetic oxygen analyzer (to check the concentration of the explosive mixture), piezoelectric pressure transducers (to measure dynamic explosion pressure), charge amplifiers, piezoresistive transducer (to monitor the pressure of the explosive mixture), piezoresistive amplifier, two oscilloscopes for viewing and recording pressure variation over time, humidity-temperature transmitter, data acquisition multimeter with relay board, AC/DC power supply, maximum experimental security gap apparatus (MESG), mixture control plant (with Bronkhorst dosers), a high-voltage power supply, spark plugs, coaxial cables , air compressor etc. The command-and-control part of the test rig is showed in Figure 3.

Fig. 3 Command and control of the test rig to perform tests in explosive mixtures

A specific mixture of hydrogen-air (with 31% H_2 v/v) was used to perform the tests in explosive mixtures in order to point out the increase of surface temperature of the test sample during the tests in explosive mixture. By burning of hydrogen in air it will usually result in water and energy [11]. The resulted energy (heat) will heat up the enclosure walls, increasing also the external surface temperature.

The concentration is close to the one of the stoichiometric hydrogen-air mixture (29,5% H_2 v/v) [12]. Also, hydrogen has the following characteristics: heat of combustion (130,8 MJ/kg), relative density to air (0,07 kg/m^3), flammability limits (4 ÷ 77 % H_2 v/v), auto-ignition temperature (560˚C) [13].

The mentioned explosive mixture represents also the testing mixture to be used in order to perform the tests with hydrogen for determination of explosion pressure.

The test mixture was introduced inside the test sample at the atmospheric pressure (0,94 bar). The two manual valves installed on the closing flanges were closed and the explosive mixture was ignited through the spark plugs.

Ten tests with hydrogen were performed. After each test the sample was purged in order to evacuate the burnt gases, humidity and to cool down the testing sample.

3 Results

The increase of temperature during the tests in explosive mixture of air-hydrogen was monitored through the thermocouples, mounted as presented in figure 2. The 6 thermocouples (T1 ÷ T6) used are placed on the testing sample as follows: T1 – on the closing flange with the gas inlet; T2, T3 and T4 – on the testing sample at distances of approximately 125 mm from each other (T3 – placed on the middle of the test sample); T5 – on the closing flange with the gas outlet; T6 – to measure the ambient temperature. The recorded temperature diagram for each point of measurement is presented in Figure 4.

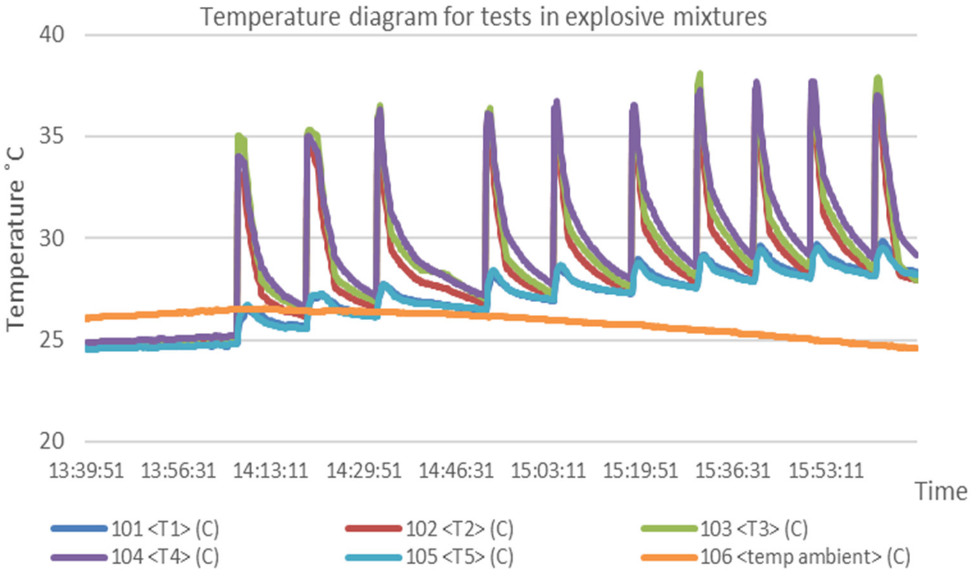

Fig. 4 Temperature diagram for tests in explosive mixtures

Also, the separate temperature diagrams for each of the measuring points are presented in Figure 5 (temperature measured by T1, T2, T3, T4 and T5).

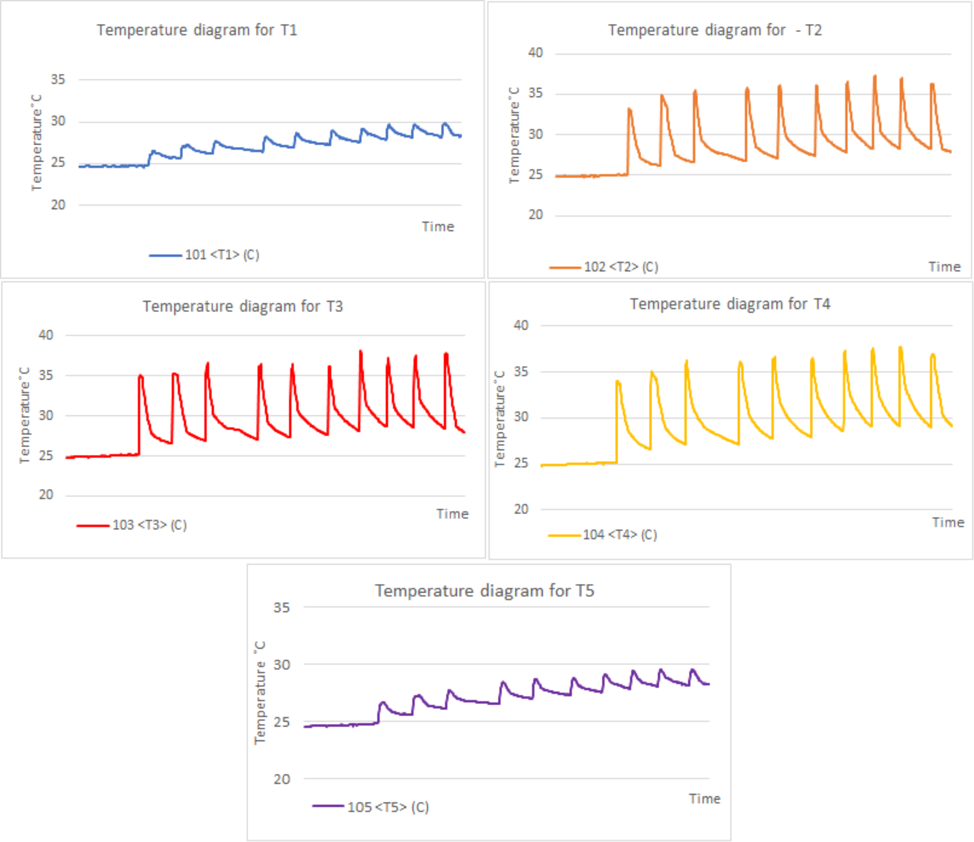

Fig. 5 Temperature diagrams recorded using thermocouples T1, T2, T3, T4 and T5

The measuring of temperature increase was related to the ambient temperature (measured by using thermocouple T6). The lowest increase of temperature was recorded by thermocouples placed on the closing flanges T1 (5,1 K) and T5 (4,8 K). A higher increase of temperature was recorded by thermocouples T2 (12,1 K), T4 (12,7 K) and T3 (13,1 K).

One can say that the lowest values for the temperature increase were recorded at the closing flanges because closing flanges are thicker than the pipe (22 mm vs 4,5 mm) and the loss of heat through conduction [14] (from the internal to the external surface of the flange) is higher. It is estimated that the other temperatures recorded on the external surface of the pipe (at thermocouples T2, T3 and T4) are higher because the heat loss through conduction [14] (from the internal to the external surface of the pipe) is lower than for the flanges. Also, it is noticed that the temperature increases measured at these points are close one to another (a maximum difference of 1 K).

On performing the tests in explosive mixtures, it was found that the surface temperature of the testing sample increased with more than 10 K at some measuring points. This is considered an important increase of temperature that can be considered when determining the maxim surface temperature of equipment with type of protection flameproof enclosure “d”.

4 Conclusions

The first part of the paper presented the general conditions to perform the tests in explosive mixtures and the tests to determine the maximum surface temperature for an equipment with type of protection flameproof enclosure. The next part indicated the test sample used and the testing methodology together with the equipment that was used in order to perform the tests in hydrogen-air explosive mixtures in order to provide an indication of the temperature increase during these tests. In the third part were presented the results that were obtained during the tests (using a hydrogen-air explosive mixture, the same as the one used to determine the reference pressure).

The obtained results showed a temperature increase of more than 10 K on the external surface of the test sample during the tests in explosive mixtures. Considering that the equipment with type of protection flameproof enclosure must be safe even in case of an internal explosion, the increase of temperature resulted during the tests in explosive mixtures, can be considered when determining the maximum surface temperature.

The work performed in this paper can be continued with measuring of temperature increase when using other gas concentrations, other explosive mixtures (e.g., methane-air, ethylene-air, propane-air, acetylene -air etc.), other enclosures (with other geometrical forms), other materials for enclosures etc.

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