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PARTICULARITIES REGARDING THE DETERMINATION OF MAXIMUM SURFACE TEMPERATURE OF JUNCTION BOXES WITH TYPE OF PROTECTION INCREASED SAFETY "E" DESIGNED FOR USE IN GASEOUS EXPLOSIVE ATMOSPHERES

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Abstract. Increased safety "e" represents a type of protection applied to electrical equipment or Ex Components designed for use in potentially explosive atmospheres generated by the presence of flammable substances in the form of gases, vapours or mists. According to this type of protection, additional measures are applied so as to exclude the possibility of occurrence of arcs, sparks and excessive temperatures even in case of abnormal operation. This type of protection cannot be applied to equipment producing electrical arcs and sparks in normal operation. This paper underlines some specific aspects regarding the determination of maximum surface temperature (such as the preparation of the test sample, determination of the hottest points and the maximum surface temperature), considering the requirements of the specific standards, in case of increased safety junction boxes designed for use in gaseous explosive atmospheres (including hydrogen).

Key words: increased safety, junction box, type of protection, maximum surface temperature.

1. GENERALITIES

Considering that increased safety "e" [[1]] can only be applied to equipment that is not producing electrical arcs and sparks in normal operation (and in specific abnormal operation), one of its' main applications is related to junction boxes. By the supplementary measures taken in the designing and construction of such equipment, even in specific abnormal operating conditions excessive temperatures, arcs and sparks are prevented to occur [[1]], [8], [11], [13].

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In the specific case of junction boxes, protected by increased safety “e”, the proper selection of insulating materials (used in the construction of enclosures and terminals), a suitable ingress protection IP for the enclosure and provision of adequate insulation distances (clearances and creepage distances) between the conductive parts subjected to electrical voltages represents the main aspects on which the explosion protection is based [[1]].

In case of increased safety equipment one of the ignition sources is represented by hot surfaces. Identification of the hottest points on the equipment is made by thermal tests. The temperatures of the hottest points are determined both on the external and internal parts of the equipment (considering that the explosive atmosphere can come in contact with the internal parts of the equipment) [[2]], [9], [10], [12], [15].

Determination of maximum surface temperature [[3], [4]], in case of increased safety junction boxes, is made in the conditions provided by SR EN IEC 60079-0 [[3]] and SR EN 60079-7 [[1]].

The specific standards considered, under the ATEX Directive [[5]], for assessment of electrical equipment with type of protection increased safety “e”, are SR EN IEC 60079-0 (providing the general requirements for equipment designed for use in explosive atmospheres) and SR EN 60079-7 (providing the specific requirements for the type of protection increased safety “e”) [1, 3].

2. SPECIFIC REQUIREMENTS FOR DETERMINATION OF MAXIMUM SURFACE TEMPERATURE IN CASE OF JUNCTION BOXES WITH TYPE OF PROTECTION INCREASED SAFETY “E”

The junction (connection) boxes, when tested to determine the maximum surface temperature are fitted with a number of terminals (considering the 'worst case' terminal). The terminals are wired using conductors of the maximum size (as specified for the particular terminal). The length of conductor connected to each terminal and contained within the enclosure shall be equal to the maximum internal dimension (three-dimensional diagonal) of the enclosure. The wiring (terminals and conductors) are so arranged that the test current is passed through each terminal and its wiring in series. In order to represent the thermal effects of bunching of conductors and also other effects of typical installations, the conductors have to be arranged in groups (of six), each with a length outside the box of at least 0,5 m. The 'worst case' terminal is that which has been found to exhibit the highest temperature rise [[1]].

A current equal to the rated current of the terminal for the application shall be passed through the series circuit. The temperature of the hottest part shall be measured when steady state conditions have been reached [[1]], [14], [17], [19], [24].

The test to determine maximum surface temperature shall be 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. Where the input voltage does not directly affect the temperature rise of the equipment or Ex Component, such as a terminal or a switch, the test current shall be increased to 110 % of the rated current [[3]], [20], [22].

The results can be affected by the conductor size, conductor entry location, terminal location / geometry, and terminal size [[3]]. For equipment which can normally be used in different positions, the temperature in each position shall be considered [[3]], [26].

The temperature measuring devices (thermometers, thermocouples, etc.) and the connecting cables must be selected and installed so that they do not significantly affect the thermal behaviour of the equipment [[3]], [21].

The final temperature is considered to have been reached when the rate of temperature rise does not exceed a rate of 2 K/h (in case of equipment designed for use in gaseous explosive atmospheres – including hydrogen) [[3]], [16], [18], [23], [25].

The measured maximum surface temperature shall not exceed for Group II equipment, temperature class T6, the temperature class, less 5 K (80°C) [[3]].

3. EXPERIMENTAL PART

To perform the testing, a sample junction box was used, with the outer approximate dimensions of 27 cm x 27 cm x 13,5 cm (L x W x H). The junction box was equipped with 36 feed-through terminals of 2,5 mm^2 installed on a mounting rail with two end clamps. Conductors with a cross section of 2.5 mm^2 were used (according to the terminal specifications) – this was the maximum cross section of a flexible conductor with a ferrule. The length of the conductors connected to each terminal and contained within the enclosure was equal to the maximum internal dimension - three-dimensional diagonal [[6]].

For the tests, a DC constant current power source TTi QPX1200S was used. To measure the current a high definition oscilloscope Lecroy HDO9304 and a current clamp CP031A were used. For the measurement of voltage, a specific channel of the multimeter Agilent 34972A (equipped with two 34901A multiplexers) was used.

The terminals were tightened at a torque of 0,55 Nm (according the terminal datasheet) with the help of a digital torque screwdriver BMS MS500S.

Type K thermocouples, with 0.25 mm diameter were used to measure the temperatures. The method for fixing the thermocouples was with mechanical pressure. Also, thermal conductive paste was used to create a better contact between the measured surface and the thermoelement. These were connected to an Agilent 34972A multimeter (equipped with 34901A multiplexers). A number of 9 thermocouples were used to measure the temperature during the tests. Also, a thermal vision camera was used, at first (in a pre-test phase) to identify the hottest areas (hottest points) so that thermocouples to be placed there.

The arrangement used for testing is presented in figure 1.

The indicated temperature class of the equipment was T6, and the test sample was tested with different currents to find the maximum current that complies with the limiting temperature of temperature class T6 (in this case 80 °C).

The junction box was placed in vertical position with free air movement (not being in contact with a wall). The testing of the junction box was made using DC in two steps:

1. Testing of the “worst case terminals” scenario

The testing was made with the junction box equipped with all the 36 terminals. The terminals were connected in series so as the testing current to pass through all the terminals. The conductors were bundled in groups of 6 [[1], [6]].

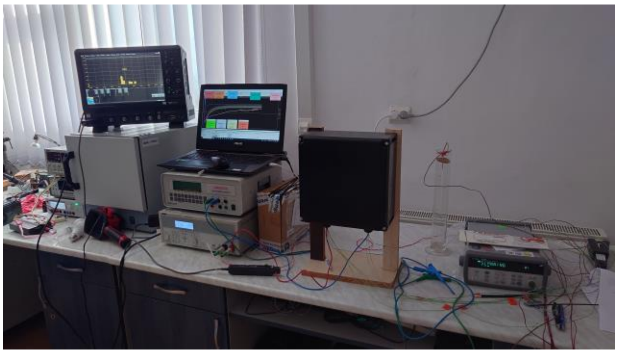

Fig.1. Testing arrangement to determine the hottest point

A specific current of 12 A was first used to determine the hotspot [[6]]. Also, to determine the maximum current for temperature class T6 (at a maximum ambient temperature of + 40 °C) the junction box was supplied to different currents (6 A, 8 A, 10 A, 13,89 A,14,67A) and the maximum current associated to temperature class T6 was calculated.

2. Testing with the rated current scenario

Testing was made on 6 terminals (the 6 terminals mounted in the middle of the 36 terminals). The other 30 terminals were not removed. The test current was set to 21 A (according to the terminal datasheet) and the hotspot was also determined [[6]].

4. RESULTS AND DISCUSSIONS

The following results were obtained after performing the specified tests.

1. Testing of the *"worst case terminals"* scenario

When testing at 12 A, the hotspot was determined to be at the second (middle) group of six conductors inside the junction box (top part). The ambient temperature considered was 22,5 °C. The final temperature at the hotspot was 53,1°C (30,6 K increase of temperature) (Figure 2). Similar values were recorded when the test was performed with an AC power source.

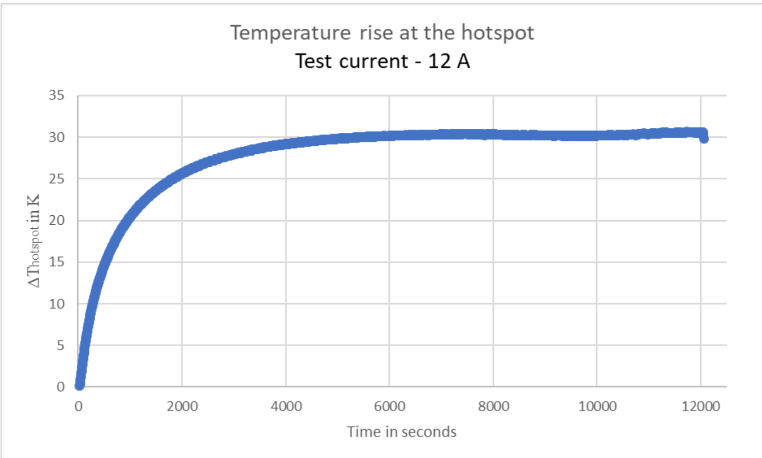

Fig.2. Temperature rise at the hotspot

Also, in the second part of the test, the temperature rise was determined for different currents in order to determine the maximum current associated to temperature class T6 as specified in Table 1. The maximum increase of temperature, according the temperature class, must also consider the safety margins associated to the temperature classes together with the maximum ambient temperature at which the product can be used (for example, in case of temperature class T6, for a maximum ambient temperature of 40°C, the safety margin is 5 K, resulting a maximum temperature increase of 40 K – the temperature shall not exceed 80°C) [[3], [5]].

Table 1. ***Temperature rise function of the testing current***

Crt. No.	**Test current [A]**	**Ambient temperature [°C]**	**Temperature rise at the hotspot [K]**
1.	6	22,5	8,0
2.	8	21,9	14,3
3.	10	22,8	21,7
4.	12	22,5	30,6
5.	13,89	22,5	39,7
6.	14,67	22,9	44,4

The maximum current for the temperature class T6 was calculated and found to be 13,91A (considering the maximum ambient temperature of 40°C). For calculation, the regression line (trendline) was used as a polynomial function of the fourth order (Figure 3). In order to have a better estimation of the heating effect induced by the electric current, the squared values of the current were used in correspondence with the temperature rise at the hotspot.

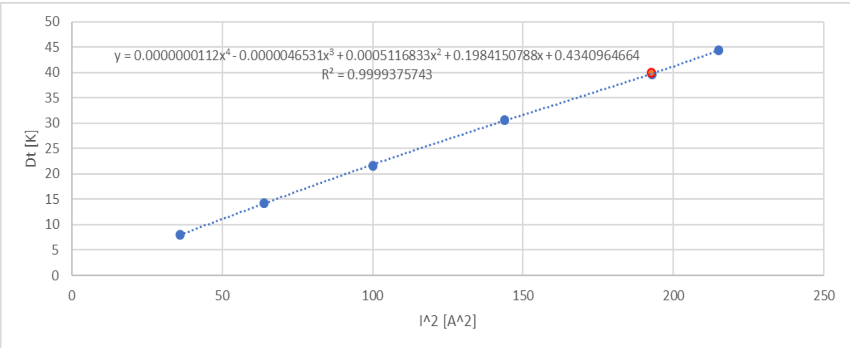

Fig.3. Polynomial regression line dependency on the squared current

2. Testing with the rated current scenario

When testing at 21 A, having only 6 terminals connected in series, the maximum temperature (hotspot) was found to be in the second (middle) group of six conductors inside the junction box (top part). The ambient temperature was 22,9 °C and the final temperature was measured as 61,6 °C (giving an increase of temperature of 38,7 °C). Also, a high temperature was measured on the internal metallic surfaces of the 2 terminals placed in the middle of the 6 terminals group (having a temperature of 60,81 °C) and giving an increase of temperature of 37,95 °C (Figure 4).

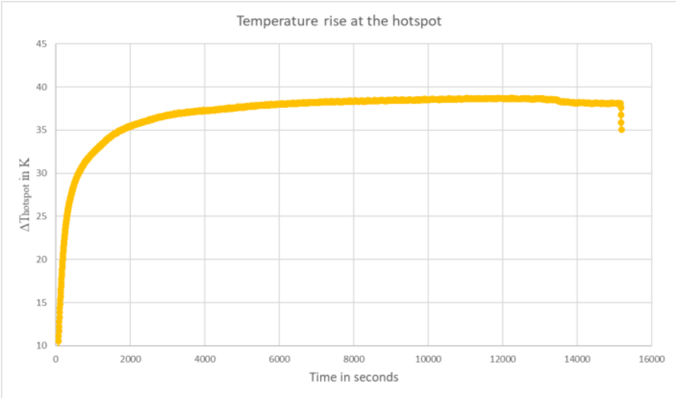

Fig.4. Temperature rise at the hotspot

When performing the tests to determine the maximum surface temperature in case of connection (junction) boxes with the type of protection increased safety, the hotspot might be found on the metallic part of the terminals or on the cables connected to the terminals under test. Even if the connection boxes are certified without the connecting cables (these are chosen by the installer according the criteria provided in the specific standard EN 60079-14 [[7]]) the hottest point might be found on the cables (conductors) inside the junction box.

When a certain temperature class is required for a junction box, equipped with a specific number of terminals, the maximum permitted current is calculated. One method used for the calculation is based on the temperature increase as a function of the squared current and using the polynomial regression (regression trendline). Also, specific software (like Microsoft Excel) can be use to identify the regression trendline and the maximum permitted value of the current.

The preparation of the test sample is very important and must consider the standard requirements for preparation (grouping the conductors in bundles of six, tightening the terminal screws at a specific torque given by the manufacturer, using thermal conductive paste to provide a more intimate thermal contact between the thermocouples and the measuring surface/point etc.).

5. CONCLUSIONS

In the beginning of the paper were analysed the required conditions to perform the determination of the maximum surface temperature in case of junction boxes with type of protection increased safety “e”.

For a certain temperature class (T6) the maximum surface temperature (maximum temperature rise) was determined together with the maximum admitted current for the “worst case terminal scenario”. The testing method and determination by calculus of the maximum admitted current were presented.

The maximum surface temperature was determined also in the case of maximum rated current scenario. In order to find the hottest point, in case of junction boxes with type of protection increased safety, temperature must be monitored both on the terminals and on the cables inside the enclosure.

The factors influencing the determination of the maximum surface temperature related to the preparation of the test sample were also presented.

This paper is important for those performing the tests for determination of maximum surface temperatures (testing laboratories and manufacturers of explosion proof junction boxes with type of protection increased safety "e" designed for use in explosive gaseous atmospheres) in order to consider the factors influencing the determination of maximum surface temperature and of the hottest points inside the enclosure.

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