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Assessing sensitivity and stability of IEC spark test apparatus as an important parameter in testing electronic devices

The article features an assessment of the sensitivity and stability of the IEC spark gap properties as an important parameter in testing electrical and electronic systems and devices. The assessed IEC spark gap, owned by EMAG's laboratory, is a device for testing the level of intrinsic safety in the circuits of electrical and electronic devices. This is done to ensure that they are explosion-proof and can work in explosive atmospheres in the mining industry (methane) as well as the chemical and petrochemical industries (hydrogen, acetylene, propane and Liquefied petroleum gas, etc.).

key words: spark gap, sensitivity, minimum igniting current.

1. INTRODUCTION

The issue of intrinsic safety and the intrinsic safety technique have long been examined by Polish research institutes engaged in the mining industry, such as the GIG Central Mining Institute – Experimental Coal Mine Barbara and the Institute of Innovative Technologies EMAG. These institutes have been conducting tests in the range of mine atmosphere explosions. In addition, they have been developing certain principles to be applied in the construction of explosion-proof electrical devices. This issue has also been discussed by world organizations involved in the safety of areas with explosion hazards [4].

It can be observed that the level of dealing with gas (methane) explosion hazards in hard coal mines is still low in many countries (Ukraine, Russia, China, Mongolia, Poland). This situation results in methane explosions with catastrophic consequences. The emission of methane in mining excavations has been growing. One of the reasons is the increasing concentration of mining works.

Higher explosion hazards are observed in Poland too. The development of electronics and the necessity to apply automation and monitoring in mines have caused a dynamic progress in intrinsically safe devices.

The sensitivity and stability of the IEC spark gap were determined on the basis of statistical tests of the device reliability.

A spark test apparatus is a mechanical measuring device whose manufacturing accuracy is a significant factor to provide proper sensitivity of the device (manufacture of contacts, rotating elements, cadmium and wolfram electrodes, etc.). What decides about the sensitivity and, at the same time, quality of the spark test apparatus manufacture, is obtaining suitable minimum igniting currents in compliance with the PN-EN 60079-11 standard.

2. IEC SPARK TEST APPARATUS

The IEC spark test apparatus is a measuring device used in testing electrical and electronic devices which affect the safety of equipment operating in explosive atmospheres. The applied testing methods depend on the group I or II [5] and the type of its electrical circuit.

Practical intrinsic safety control of an intrinsically safe circuit is conducted in compliance with the following standards: PN-EN 60079-0: Explosive atmospheres – Part 0: Equipment - General requirements, PN-EN 60079-11: Explosive atmospheres – Part 11: Equipment protection by intrinsic safety 'i'.

Almost all world and Polish testing laboratories use the IEC spark test apparatus (Fig. 1) which is a universal device recommended for testing RLC intrinsically safe circuits.

The IEC spark test apparatus is recommended by the International Electrotechnical Commission. It was developed in Germany in 1961 and put into use by the standard VDE 0170 d/017 and d/2.65 [1] as an obligatory device for testing intrinsic safety.

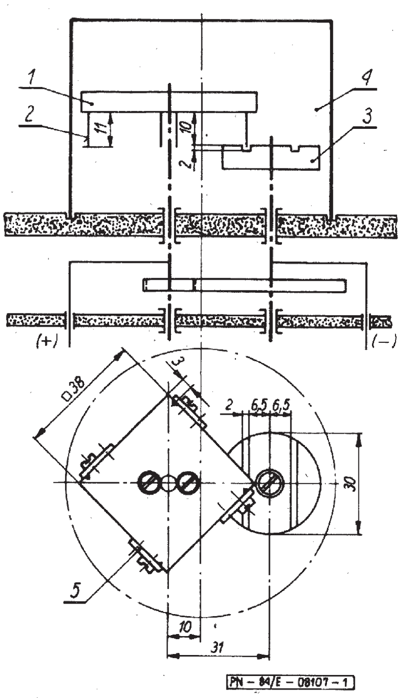

Fig. 1. Electrodes of IEC spark gap [5].
1,5 – handle of wolfram electrodes, 2 – wolfram electrode, 3 – cadmium electrode, 4 – chamber

The basic data of the spark test apparatus are the following:

– Four wolfram electrodes, one cadmium electrode;
– Rotational speed of the disc with wolfram electrodes – 80 rotations/minute;
– Proportion of rotational speed of the disc with wolfram electrodes to the cadmium disc – 50:12;
– Volume of the chamber with the explosive mixture – at least 250 cm^3;
– Capacity of the circuits at open electrodes – no more than 30 pF;
– Inductance of the circuit at closed electrodes – no more than 3 μH;
– Admissible currents cannot exceed 2 A in a normal state; if the current has a higher value, it is necessary to modify the spark test apparatus using other, thicker wolfram electrodes.

The IEC spark test apparatus is now the most commonly used device for testing intrinsically safe devices, circuits, lines, etc.

3. CONTROLLING SENSITIVITY AND STABILITY OF SPARK TEST APPARATUS PROPERTIES

In order to put the IEC spark test apparatus into use, it is necessary to test its sensitivity and to repeat the measurements in order to have better knowledge about the measuring device.

An important parameter of the spark test apparatus is to obtain the lowest possible value of minimum igniting current I_{zm} [2, 3]. This current differs depending on the parameters of the DC control circuit, e.g. for inductance circuit at 24 V, with inductance from 95 mH to 100 mH, the minimum igniting current is 110 mA. It also depends on the test mixture which is different for different groups and subgroups of devices [1].

The sensitivity of the spark test apparatus depends on many factors, such as:

– Type and selection of electrodes; the most sensitive were four wolfram electrodes and one cadmium disc electrode.
– Settings and proper installation of wolfram electrodes.
– Parameters of the control circuit (precision of contacts, etc.)

The repeatability of measurements depends on:

– Explosive mixture put into the chamber.
– Accuracy of the spark gap manufacture (preserving its parameters in time).
– Settings of wolfram wires – whether they are straight or curved, whether they were cut properly.

The sensitivity of the spark gap was tested based on the spark gap owned by the EMAG Institute. The device was designed and manufactured in compliance with PN-EN 60079-11, by EMAG's employees.

The tests were conducted during 40 successive days for a standard inductive circuit with the following parameters:

– voltage: 24 V,
– inductance: 95 mH,
– current: 110 mA, 107,5 mA, 105 mA, 102,5 mA, 100 mA.

The results of the tests are placed in Table 1.

Table 1.

Dependence of probability p on current I for standard inductive circuit

	110 mA		107,5 mA		105 mA		102,5 mA		100 mA	
	p*	m/n	p*	m/n	p*	m/n	p*	m/n	p*	m/n
series 1	0,0943	20 / 212	0,0402	14 / 348	0,0246	14 / 568	0,0070	14 / 1991	0,0034	14 / 4089
series 2	0,1042	20 / 192	0,0407	14 / 344	-	-/-	-	-/-	-	-/-
series 3	0,1031	20 / 194	0,0358	14 / 391	0,0274	14 / 511	-	-/-	-	-/-
series 4	0,1143	20 / 175	0,0419	14 / 334	-	-/-	0,0066	14 / 2119	-	-/-
series 5	0,0870	20 / 230	0,0401	14 / 349	0,0250	14 / 560	-	-/-	-	-/-
series 6	0,0935	20 / 214	0,0439	14 / 319	-	-/-	-	-/-	0,0033	14 / 4298
series 7	0,1105	20 / 181	0,0426	14 / 329	0,0261	14 / 536	0,0066	14 / 2112	-	-/-
series 8	0,1000	20 / 200	0,0390	14 / 359	-	-/-	-	-/-	-	-/-
series 9	0,1205	20 / 166	0,0420	14 / 333	0,0297	14 / 471	-	-/-	-	-/-
series 10	0,0823	20 / 243	0,0427	14 / 328	-	-/-	0,0064	14 / 2178	-	-/-
series 11	0,0913	20 / 219	0,0447	14 / 313	0,0278	14 / 504	-	-/-	0,0035	14 / 3979
series 12	0,1058	20 / 189	0,0414	14 / 338	-	-/-	-	-/-	-	-/-
series 13	0,1156	20 / 173	0,0419	14 / 334	0,0265	14 / 529	0,0067	14 / 2087	-	-/-
series 14	0,0939	20 / 213	0,0439	14 / 319	-	-/-	-	-/-	-	-/-
series 15	0,1183	20 / 169	0,0390	14 / 359	0,0320	14 / 437	-	-/-	-	-/-
series 16	0,0897	20 / 223	0,0397	14 / 353	-	-/-	0,0070	14 / 1992	0,0035	14 / 3970
series 17	0,0926	20 / 216	0,0401	14 / 349	0,0238	14 / 589	-	-/-	-	-/-
series 18	0,0840	20 / 238	0,0426	14 / 329	-	-/-	-	-/-	-	-/-
series 19	0,0939	20 / 213	0,0393	14 / 356	0,0257	14 / 544	-	-/-	-	-/-
series 20	0,0995	20 / 201	0,0420	14 / 333	-	-/-	0,0066	14 / 2109	0,0032	14 / 4420
$\frac{\Sigma m}{\Sigma n}$	0,0985	400 / 4061	0,0411	280 / 6817	0,0267	140 / 5249	0,0067	98 / 14588	0,0034	70 / 20756

Where:
n – number of rotations of the disc with wolfram electrodes,
m – number of initiated explosions,
$p = \frac{m}{n}$ - probability of the explosive mixture ignition.

The above table presents how the probability of explosion changes with the changing amperage of the current in the control circuit. If the current decreases by 10%, the probability of the explosion mixture ignition drops by almost 30 times. Therefore it is so important to check the sensitivity of the spark test apparatus before each testing with the use of a suitable testing set (24 VDC/ 110 mA DC and 95 mH).

The calculation of minimal currents of the ignition is more complicated as it is necessary to determine the calibration curve of the spark test apparatus (Fig. 2), along with its uncertainty.

The below formulas [1] are indispensable to determine the straight:

$$X = \log I \quad (1)$$

$$Y = \log p \quad (2)$$

$$b_1 = \frac{\Sigma(X_i - \bar{X})(Y_i - \bar{Y})}{\Sigma(X_i - \bar{X})^2} \quad (3)$$

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$$b_0 = \bar{Y} - b_1\bar{X} \quad (5)$$

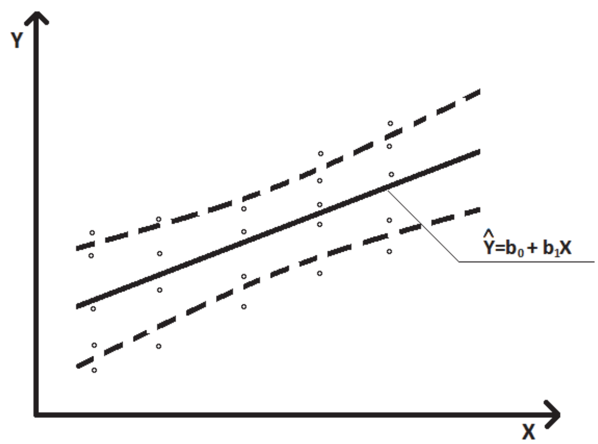

Fig. 2. Calibration curve of the spark test apparatus with the considered measurement uncertainty

Confidence interval:

$$\mathrm{P}\left(\frac{\mathrm{m}}{\mathrm{n}}-k\sqrt{\frac{\frac{\mathrm{m}}{\mathrm{n}}\left(1-\frac{\mathrm{m}}{\mathrm{n}}\right)}{\mathrm{n}}}<p<\frac{\mathrm{m}}{\mathrm{n}}+k\sqrt{\frac{\frac{\mathrm{m}}{\mathrm{n}}\left(1-\frac{\mathrm{m}}{\mathrm{n}}\right)}{\mathrm{n}}}\right) \quad (6)$$

where:
k – coverage factor $k = 2$,
m – number of initiated explosions (trials),
n – total number of rotations of the disc with wolfram electrodes for the given trial.

Minimum igniting currents I_{zm} for the tested spark test apparatus were the following:

Minimum igniting currents I_{zm} [mA]	**Average minimum igniting current $\overline{I_{zm}}$ [mA]**
98,5; 101,5; 97,3; 99,7; 96,1; 98,6; 99,2; 101,3; 98,2; 99,2; 98,0; 101,2; 99,0; 99,4; 97,3; 98,6; 97,6	98,8

As it can be observed, the minimum current of the ignition is lower than in a typical control circuit. This results from the assumption that the calibration curve is linear and that there is a probability of the mixture ignition.

4. CONCLUSIONS

The conducted tests demonstrated that the spark test apparatus manufactured in compliance with the standard [5] and used by the EMAG Institute is a very sensitive device with a high level of the tests repeatability. The achieved minimum igniting currents I_{zm}, and their repeatability prove that the measurement device ranks high in its category and is competitive against the devices used in other institutes. The spark test apparatus enables to carry out tests in compliance with testing procedures stipulated by the standard [5] and ensures the tests reliability.

Further works related to the IEC spark test apparatus in EMAG will focus on conducting comparative tests for a properly prepared testing circuit – the tests of intrinsically safe power supply units [6]. These works will be done in co-operation with institutes which have PCA accreditation (Polish Centre of Accreditation) in the scope of testing intrinsic safety of electrical devices and have IEC spark test apparatus at their disposal (GIG Institute – Barbara). The tests are indispensable for EMAG to begin the PCA accreditation process.

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References

1. Frączek J.: Aparatura przeciwwybuchowa w wykonaniu iskrobezpiecznym (Explosion-proof intrinsically safe apparatus). Śląskie Wydawnictwo Techniczne 1995.
2. Frączek J.: Metody analizy dopuszczalnych prądów bezpiecznych w iskrobezpiecznych urządzeniach kontrolno-pomiarowych (Methods for analyzing admissible safe currents in intrinsically safe control and measurement devices). Zeszyty Naukowe Politechniki Śląskiej, Automatyka 57, 1980.
3. Frączek J.: Podstawy oceny zagrożenia wybuchowego od urządzeń kontrolno-pomiarowych w wykonaniu iskrobezpiecznym w aspekcie stosowania iskiernika IEC (Assessment of explosion hazards from control and measurement intrinsically safe devices with respect to an IEC spark-gap). Zeszyty Naukowe Politechniki Śląskiej, Automatyka 38, 1977.
4. Magison E.: Electrical Instruments in Hazardous Locations. ISA 4th Edition 1998.
5. PN/EN 60079-11:2012: Atmosfery wybuchowe. Część 11: Zabezpieczenia urządzeń za pomocą iskrobezpieczeństwa „i" (PN/EN 60079-11:2012: Explosive atmospheres. Part 11: Equipment protection by intrinsic safety "i").
6. Skoropacki W., Miśkiewicz K.: Iskrobezpieczne zasilacze prądu stałego – stan obecny, perspektywy rozwoju (Instrinsically safe DC power supply – state of the art, development perspectives). Mechanizacja i Automatyzacja Górnictwa 453, 2008.

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