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RESEARCH ON THE SENSITIVITY TO IGNITION OF DUST AIR MIXTURES

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Abstract: Potentially explosive atmospheres generated by dust / air mixtures may be initiated by various ignition sources. The assessment of the risk of ignition of an explosive air / dust mixture involves first of all the sensitivity of the explosive atmosphere to ignition, respectively the minimum ignition energy of the explosive mixture, being necessary then an analysis of the possibilities of formation and initiate this explosive mixture. This paper presents two methods for determining the minimum ignition energy, with a description of the equipment used and the operating principles.

Keywords: dust-air mixture, explosive atmospheres, minimum ignition energy,

1. GENERALITIES

The continuous evolution of human society from a technical and economic point of view has led to the need to use new materials to make various products necessary for human society, which involves the emergence of a large number of chemical compounds in the form of combustible dusts and powders. The production, processing, handling and storage of these combustible dusts can often lead to potentially explosive atmospheres, generated by the mixture of these dusts with air, both inside the plant and in the atmosphere around the technical equipment.

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Dust explosions may be classified as being either "primary" or "secondary" in nature. Primary dust explosions may occur inside processing equipment or similar enclosures, and are generally controlled by relieving the pressure through purpose-built ducting to the external atmosphere. Secondary dust explosions are the result of dust accumulation inside a building being agitated and ignited by the primary explosion, resulting in a much more dangerous uncontrolled explosion that can affect the entire structure. Historically, fatalities from dust explosions have largely been the result of secondary dust explosions.

It is well known that an explosion may occur if the dust / fuel powder is present in suspension in admixture with air (with sufficient oxygen) within the explosive limits, corroborated with the existence of a source of initiation with sufficient ignition energy, and the pentagon can be defined the explosion shown in Figure 1 [4].

Fig. 1 – Pentagon of ignition to combustible dusts

As dust explosions often cause significant damage to the environment, sometimes in conjunction with even human losses, it is necessary to take and implement appropriate measures to prevent a dust explosion from occurring. These measures refer primarily to the prevention of the formation of an explosive dust-air atmosphere, followed by the prevention of the appearance of ignition sources and then the limitation of the effects of an explosion [6].

If, for various reasons, a potentially explosive air / dust atmosphere cannot be prevented, it is necessary to assess the risk of ignition of the existing air / dust explosive atmosphere. This can be done by knowing the ignition sensitivity of the existing potentially explosive dust / air atmosphere, characterized by the minimum ignition energy. By knowing the minimum ignition energy, together with the amount of energy released by an ignition source (electrical spark, mechanical in nature or due to an electrostatic discharge), it can be determined whether or not the ignition takes place. For the most common combustible dusts, which are used in various industries, the minimum ignition energy is known, but for other combustible dusts, which have appeared more recently, this parameter must be determined which defines the ignition sensitivity of the dust / air mixture.

For the determination of the minimum ignition energy, there is a standardized method presented in the European standard SR EN 80079-20-2:2016, which involves use as an explosion vessel either of the KSEP-20 installation, or of the modified

Hartmann tube. However, following research conducted by INCD INSEMEX specialists in their own laboratories, it was found that the method for determining the minimum ignition energy described in the said standard needs to be improved, because by using this method the results obtained on the minimum ignition energy value are estimated.

Therefore, this paper describes the methods for determining the minimum ignition energy, namely: the standardized method that uses the KSEP-20 plant as an explosion vessel and by using Hartmann tube, respectively a new method based on the measurement of the discharge energy, which uses the MIE- D.

2. METHODS FOR DETERMINING MINIMUM IGNITION ENERGY (MIE) ACCORDING TO SR EN 80079-20-2 STANDARD

According to SR EN 80079-20-2 standard, the minimum ignition energy is defined as the lowest energy accumulation on a capacitor and which is sufficient to cause ignition of the lightest dust mixtures under the specified test conditions.

The minimum ignition energy for dust / air mixtures varied depending on several parameters, including: particle size distribution, moisture / solvent content, and test method / equipment used.

In the laboratories of the INCD INSEMEX Petroșani from Romania, the minimum ignition energy of explosive dust / air mixtures can be determined by estimative methods or quantitative methods, more specifically:

- Estimation method using a 20 litre test cell (vessel) based on which only an estimated value of the minimum ignition energy can be determined.
- Quantitative method using modified Hartmann tube which provides more accurate values for the minimum ignition energy.

2.1 Estimation method using a 20 litre test cell (vessel) for determination of minimum ignition energy (MIE)

To determine MIE by the estimation method, one of the apparatus used is KSEP-20. This apparatus consists of an explosion-proof spherical blast-furnace made of stainless steel with a volume of 20 dm3 - Figure 2. A water jacket has the role of absorbing the heat produced by the explosions. To perform the test, the dust to be analysed is dispersed within the sphere of the pressure dust receptacle through a quick acting valve and a dispersing nozzle. The quick acting valve is pneumatically opened and closed by an auxiliary piston. The compressed air valves are electrically activated. The ignition source is located in the centre of the sphere.

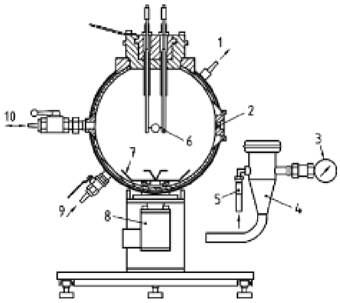

Fig. 2 The KSEP-20 test facility

As can be seen in Figure 2, the KSEP-20 test facility is composed of the following elements: water outlet (1), pressure transducers (2), manometer (3), dust container (4), air intake opening (5), ignition source (6), spray nozzle (7), quick-acting valve (8), inlet for water (9), exhaust outlet (10).

Depending on the parameter to be determined, the commands to the test facility are transmitted using an interface and a dedicated software. Two piezoelectric pressure transducers are recorded on the inner wall of the explosion vessel recording variations in the pressure of the explosion produced inside the vessel. After the test, the data obtained using this software is collected, generating based on recorded data the graphs necessary for the evaluation of the explosive parameters [3].

2.2 Quantitative method using modified Hartmann tube for determination of minimum ignition energy (MIE) [5]

In this case a modified Hartmann glass tube with a volume of 1,2 litre is used as the explosion container - figure 3. The dust dispersion system at the base of the tube is of the mushroom type around which the sample is spread freely.

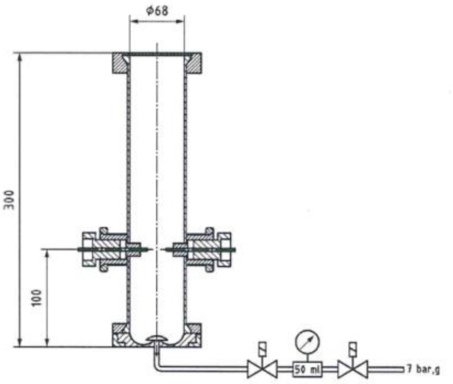

Fig. 3 Hartmann tube modified

The dust stored at the base of the Hartmann tube is dispersed by a stream of compressed air, air released from a 50ml tank by a dispersion system with electro-pneumatic valves. The tank contains compressed air at a pressure of 7 bar (700 kPa). Dust scattered in the glass cylinder is ignited by an electric spark produced between two electrodes.

For an energy of less than 10 mJ the spark is generated by a system consisting of two fixed electrodes (figure 3) and a high voltage relay generation circuit shown in figure 4. In this electronic circuit, the following are found: U_o is charging voltage, U_p is discharge voltage, C_o is electrical storage capacity, C_p is parasitic electrical capacity, L represent inductance (additional) and HVR represent high voltage relay.

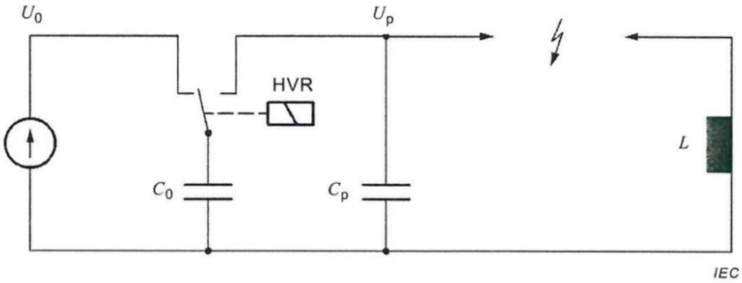

Fig.4 System with two electrodes and discharge by high voltage relay

At very low energies the inevitable parasitic capacity of the electrode assembly has the same order of magnitude as the electrical storage capacity. Therefore, at this stand, the parasitic capacity is kept constant and the discharge voltage must be calculated as follows (1):

$$U_p = U_0 \cdot C_0 / (C_0 + C_p) \quad (1)$$

From here you can calculate the energy of the E spark as (2):

$$E = 0{,}5 \cdot (C_0 + C_p) \cdot U_{p2}) \quad (2)$$

The discharge capacitor C0 will be charged with a potential equal to (3):

$$Q_0 = U_0 \cdot C_0 \quad (3)$$

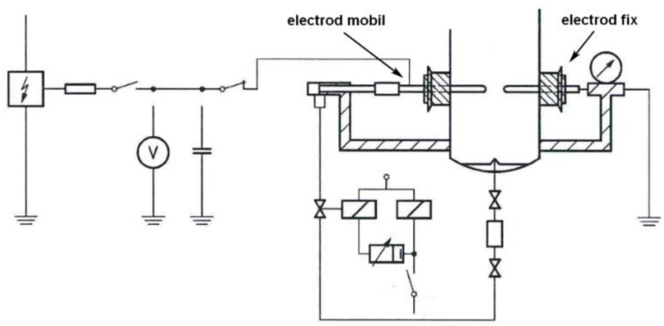

Fig. 5 Hartmann tube modified with two electrodes, a mobile electrode

After switching the high voltage relay "HVR", the load remains but the voltage U_0 will decrease to the value U_p. For energies greater than 10mJ, ignition occurs by moving an electrode from the system with two electrodes (figure 5).

During the movement of the electrodes, the energy stored in the capacitor C0 decreases due to the corona-type current flowing through the tips of the electrodes. So this type of trigger is allowed only with energy values higher than 10 mJ, where these corona type losses are negligibly small. Figure 6 shows the scheme of this system, in which we have the following: U_o is charging voltage, C_o is electrical storage capacity, L represent inductance (additional), CR is charging relay and ME represent the mobile electrod.

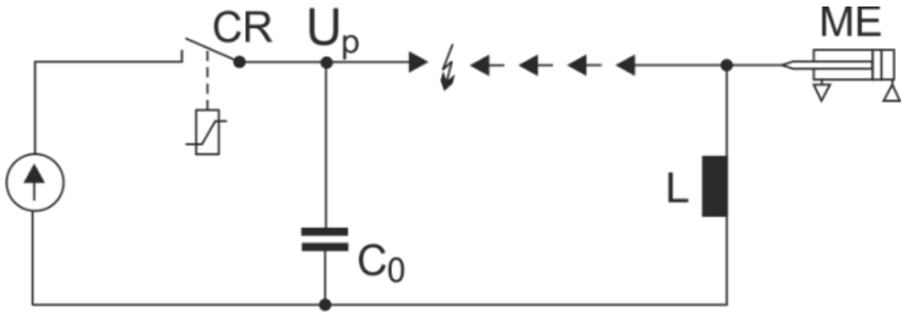

Fig. 6 Triggering by moving an electrode from the system with two electrodes

At start-up, the mobile electrode is in the initial position. In this position, the gap between the two electrodes is so large that a discharge will never occur. After opening the charging relay, the electrode (ME) is moved rapidly through a pneumatic system to reach the preset minimum distance of 6 mm between the electrodes. The disruptive discharge occurs before the end position is reached

The spark energy E is calculated according to the following formula (4):

$$E = 0{,}5 \cdot C_0 \cdot U_{p2} \tag{4}$$

3. NEW METHOD BASED ON THE MEASUREMENT OF THE DISCHARGE ENERGY

Due to the fact that the estimation method is outdated, INCD INSEMEX acquired in 2018 a complex equipment MIE-D 1.2, to determine the minimum ignition energy of explosive dust / air mixtures based on the quantitative determination method (Figure 7), which is produced by OZM Research from Czech Republic.

This equipment for MIE determination allows for the start time and dust concentration to be changed so as to determine the most suitable conditions for the explosion.

Research has shown that the explosion of dust is influenced by several basic parameters [1], among which:

- Delay between dust dispersion and spark production,

- The method of dispersing the powder which is influenced by the size and shape of the dispersion nozzle,

- The characteristics of the spark, i.e. duration and energy which are influenced by the electric circuit design, by the values of capacitance, inductance and resistance,

- The amount of dust and the particle size distribution of the dust placed in the lower part of the explosion chamber before the experiment.

Fig. 7 MIE-D 1.2 equipment

3.1 Description of the equipment for determining minimum ignition energy of an explosive mixture of dust / air MIE-D 1.2

The equipment for determining the minimum ignition energy of explosive dust / air mixtures includes the following components (Figure 8): Hartmann glass tube (1), control panel (2), Sliding door equipped with a closed-position safety sensor (3), emergency stop button (4), high voltage switch (5), high voltage presence indicator (6), start button (7), function indicator (8), outlet for exhaust fumes (9).

Fig. 8 Presentation of the equipment components (front view) MIE-D 1.2 [2]

The logic operating diagram of the equipment for determining the minimum ignition energy is shown in Figure 9.

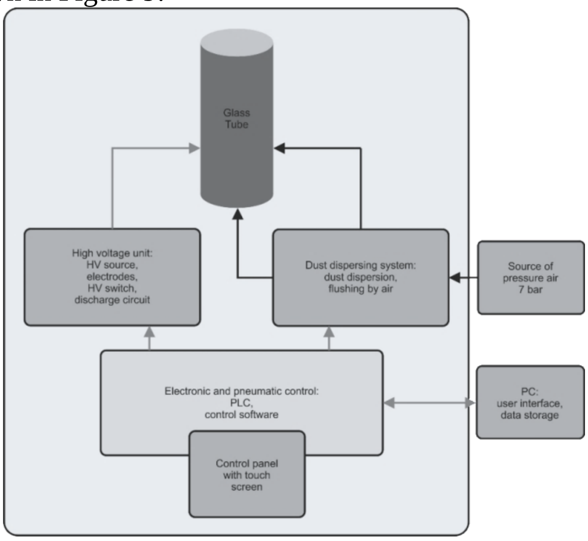

Fig. 9 Logical operating scheme for equipment to determine the minimum ignition energy of explosive dust / air mixtures [2]

In accordance with the requirements and recommendations of EN 80079-20-2: 2016, dust dispersion and mixture ignition take place in a Hartmann tube with a capacity of 1.2 litres.

The dust deposited at the base of the Hartmann tube is dispersed by a compressed air stream, air released from a 50 ml tank of a dispersion system with electro-pneumatic valves. The tank contains compressed air at a pressure of 7 bar (700 kPa).

The electrostatic discharge is generated in the high voltage unit. The unit consists of a high voltage source, a set of internal capacitors, a high voltage switch, a discharge circuit, high voltage electrodes and electro-pneumatic valves for switching capacitors and measuring modes.

Both dust and high voltage systems are controlled by a Programmable Logic Controller (PLC), which communicates with the operator through the touch screen control panel. With the exception of the control panel, the entire system is located in the booth casing. The clear acrylic glass door, equipped with a closed-position safety sensor, protects the operator and at the same time enables the user to follow the course of the experiment to see if the ignition has occurred.

The MIE-D Lab program guides the user throughout the experiment and also provides an evaluation and archiving of the data obtained. The program is installed on a separate computer, thus eliminating the influence of common operating systems (for example, Windows) on the control program running on the PLC device and thus increasing the safety of operation. Sample preparation is also not connected to the device itself.

4. CONCLUSIONS

The minimum ignition energy of air / dust mixtures can be determined using an estimation method, as presented in SR EN 80079-20-2:2016, or a new direct method, which is based on the measurement of the discharge energy.

The first part of the paper presents the indirect method for determining the MIE using the KSEP-20 test facility together with the modified Hartmann tube (estimation method).

The second part of the paper presents a direct method for determining the MIE, using the MIE-D 1.2 equipment, a method that is based on measuring the discharge energy.

Considering the methods presented, it has been found that the method using direct measurement of discharge energy provides more accurate results, which is why it is considered necessary to revise the test standard.

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