

# ASSESSMENT OF NON-ELECTRICAL EQUIPMENT INTENDED USE IN FIREDAMP UNDERGROUND MINES, RELATED TO EUROPEAN DIRECTIVE ATEX 2014/34/UE

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**Abstract.** When using equipment and components in hazardous locations must be made checks to see if the ignition hazards may occur, considering the ignition processes. If there is the possibility of occurrence the fire hazards must be take measures for eliminate ignition sources to the hazardous location. If this is not possible, additional protective measures should be implemented to ensure an adequate protection level.

The measures shall be made the ignition sources harmless or shall be reduce the likelihood of occurrence of effective ignition sources. This may be achieved through an adequate design and construction of equipment and components, by operating procedures and also by adequate measuring and control systems.

Protective measure depends on the probability of occurrence an explosive atmosphere and the consequences of possible explosions. In this sense the classification and conformity assessment of non-electrical equipment is achieved through a difference between different categories of equipment, as specified in Directive 2014/34/UE – ATEX.

The conformity assessment methods of non-electrical equipment intended for underground use presented in the paper, have as main purpose to increase the level of safety and protection of workers in the mining industry. The applied measures must make the ignition sources harmless or shall reduce the occurrence probability of the ignition sources.

**Keywords:** explosive atmospheres, hot surfaces, thermal image, explosion protection

## ОЦІНКА НЕЕЛЕКТРИЧНОГО ОБЛАДНАННЯ, ЩО ПОВ'ЯЗАНЕ З ЄВРОПЕЙСЬКОЮ ДИРЕКТИВОЮ АТЕХ 2014/34 / UE ТА ЙОГО ПРЕДМЕТНОГО ВИКОРИСТАННЯ В ПІДЗЕМНИХ ВИРОБКАХ З РУДНИЧНИМ ГАЗОМ

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**Анотація.** При використанні обладнання та компонентів у небезпечних місцях повинні бути проведені перевірки, чи не може виникнути небезпека займання, з урахуванням процесів займання. Якщо існує ймовірність виникнення пожежі, необхідно вжити заходів щодо усунення джерел займання в небезпечному місці. Якщо це неможливо, слід вжити додаткових захисних заходів для забезпечення належного рівня захисту.

Заходи повинні зробити джерела запалення нешкідливими або зменшити ймовірність виникнення ефективних джерел займання. Цього можна досягти за допомогою адекватного проектування та побудови обладнання та компонентів, експлуатаційних процедур, а також за допомогою адекватних систем вимірювання та контролю.

Захисний захід залежить від ймовірності виникнення вибухонебезпечної атмосфери та наслідків можливих вибухів. У цьому сенсі класифікація та оцінка відповідності неелектричного обладнання досягається шляхом різниці між різними категоріями обладнання, як зазначено в Директиві 2014/34 / UE - ATEX.

Представлені в роботі методи оцінки відповідності неелектричного обладнання, призначеного для підземного використання, мають на меті підвищити рівень безпеки та

захисту працівників гірничодобувної галузі. Застосовувані заходи повинні зробити джерела займання нешкідливими або зменшити ймовірність появи джерел займання.

**Ключові слова:** вибухонебезпечна атмосфера, гарячі поверхні, теплові зображення, вибухозахист

## **1. Introduction**

When using equipment and components in dangerous locations, checks should be made to see if ignition hazards may occur, taking into account the ignition processes. If there is a possibility of ignition hazards, measures must be taken to remove the ignition sources from the hazardous location. If this is not possible, additional protection measures must be implemented to ensure an adequate level of security.

The measures implemented must make the ignition sources harmless or limit the probability of the ignition sources to occurring. This can be achieved through adequate equipment and component design and construction, operating procedures and adequate measurement and control systems as well.

The magnitude of protection measures depends on the probability of an explosive atmosphere occurring and the effects of possible explosions. In this sense, the classification of non-electrical equipment is made by differentiating between various categories of equipment, as specified in Directive 2014/34 / EU. These categories reflect the requirements for different hazardous areas and hazard conditions.

Non-electrical equipment for mines susceptible to firedamp and/or flammable dust is classified in group I. Which includes two categories, depending on the level of security provided:

- Category M1
- Category M2

### **1.1 Non - electrical equipment Group I**

#### **a) Category M1**

Equipment designed and, where necessary, equipped with additional special means of protection to be capable of functioning in conformity with the operational parameters established by the manufacturer and ensuring a very high level of protection.

The equipment in this category is intended to be used in the underground parts of the mines as well as in those parts of the surface installations of these mines endangered by firedamp and / or combustible dust.

The equipment in this category is intended for use in both underground parts of mines and those parts of surface installations of such mines that are endangered by firedamp and/or combustible dust.

The equipment shall continue to remain functional even in the event of rare incidents relating to the equipment with an explosive atmosphere present, and feature such protective measures that:

- in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection,
- or the requisite level of protection is assured in the event of two faults occurring independently of each other.

#### **b) Category M2**

The equipment in this category is intended for use in both underground parts of mines and those parts of surface installations of such mines that are endangered by firedamp and/or combustible dust. If an explosive atmosphere occurs, it must be possible to switch off the equipment.

The constructional explosion-protection measures ensure the required degree of safety during normal operation, even under severe operating conditions and, in particular, in cases of rough handling and changing environmental influences.

Two equipment protection levels (EPL) are defined for firedamp-endangered mining works:

- EPL Ma: Equipment with a very high protection level that affords the necessary degree of safety. The equipment represents no risk of ignition in normal operation or in the event of predictable or rare faults/malfunctions – even if it is still in operation during a gas leak;

- EPL Mb: Equipment with a high protection level that affords the necessary degree of safety. The equipment represents no risk of ignition in normal operation in the period between the occurrence of the gas leak and switching off the equipment.

## **1.2 Design and construction of non-electrical equipment regarding the avoidance of generation of ignition sources**

When using equipment and components in hazardous conditions, checks should be made to see if ignition hazards may occur, taking into account the ignition processes. If there is a possibility of ignition hazards, actions must be taken to eliminate the sources of ignition in these situations. If this is not possible, protective measures must be implemented.

Protective measures must make the ignition sources inoffensive or reduce the likelihood of actual ignition sources occurring. This can be achieved through proper design and construction of equipment and components, operating procedures and also appropriate measuring and control systems.

## **1.3 Requirements regarding the prevention of the generation of ignition sources such as hot surfaces for mechanical equipment from Group I - Mining and adjacent areas**

If an explosive atmosphere comes in contact with a heated surface, ignition can occur. Not only can a hot surface itself act as an ignition source, but a layer of combustible dust that comes in contact with a hot surface and ignited by itself can also act as an ignition source for an explosive atmosphere.

The ability of a heated surface to cause ignition depends upon the type and concentration of the specific substance in air mixture. This ability increases with the temperature rise and surface area increase. In addition, the temperature that triggers the ignition depends on the size and shape of the heated body, on the gradient of the concentration in the surface's surrounding area and, in a certain amount, on the surface's material. When an explosive atmosphere is leaking along hot surfaces, due to the short time of being in contact, a much higher surface temperature could be required.

If the explosive atmosphere remains in contact with the hot surface for a relatively long time, preliminary reactions may occur, for example cold flames, so that several highly flammable decomposition products are formed, which ignite the initial atmospheres.

In addition to easily recognizable hot surfaces such as radiators, drying cabins, heating coils and others, mechanical and machining processes, moving parts of the equipment can also generate dangerous temperatures. These processes also include equipment and components that convert mechanical energy into heat, i.e. all types of clutches and couplings, brakes and braking systems, bearings, power transmission systems, etc. In addition, all moving parts in bearings, shaft passages, bushings, etc., can become sources of ignition if not properly lubricated. In the sealed housings of moving parts, the entry of foreign bodies or the movement of the shaft can also lead to friction which, in turn, can lead to high surface temperatures, in some cases quite quickly.

Temperature increases due to chemical reactions (egg with lubricants and/or cleaning solvents) must also be considered.

If the risks caused by hot surfaces have been identified, depending on the type of explosive atmosphere (firedamp and/or combustible dust) and the group / category and mode of operation (normal, expected malfunction or rare malfunction) reach the specific requirements for equipment and components.

## **1.4 Requirements regarding the prevention of the generation of mechanical spark ignition sources for mechanical equipment from Group I - mining and adjacent areas**

The friction sparks produced by the cutting tools of the cutting machines during the hard rock cutting operation containing quartz or ferrite pyrite inclusions cannot always be avoided, but the

risk of ignition of the gas / dust atmosphere can be considerably reduced by the use of machine-mounted water spray systems or using cutting tools specially designed for this purpose. If the ignition hazard has been identified, a water spray system must be installed around the cutting head so that any friction / impact sparks are extinguished, the amount of dust in the suspension is reduced and fresh air is directed to the instrument. cutting to dilute the gas resulting from the operation process. These water spray systems must be monitored and controlled with the machine control system to ensure that cutting cannot be performed without the water spray system operating as designed.

If the risk caused by the mechanically generated sparks have been identified, depending on the type of explosive atmosphere (underground mines and adjacent installations) and the category, the equipment must meet the following requirements:

- for category M1: Equipment, protective systems and components which, even in the case of rare equipment failures, may generate mechanical, friction, impact or abrasion sparks are not permitted.

- for category M2, equipment, protective systems and components which generate friction, impact or abrasion sparks during normal operation and under severe operating conditions, in particular in rough handling, under the influence of changes in the environment, must be fitted with adequate means of protection for prevent the ignition source from becoming effective. The use of light metals for the uncoated surfaces of equipment, protective systems and components (cases) is permitted only if:

- the total content of aluminum, magnesium, titanium and zirconium does not exceed 15%;
- the total content of magnesium, titanium and zirconium does not exceed 6%.

## **2. Methods and techniques for risk assessment (explosion risk assessment)**

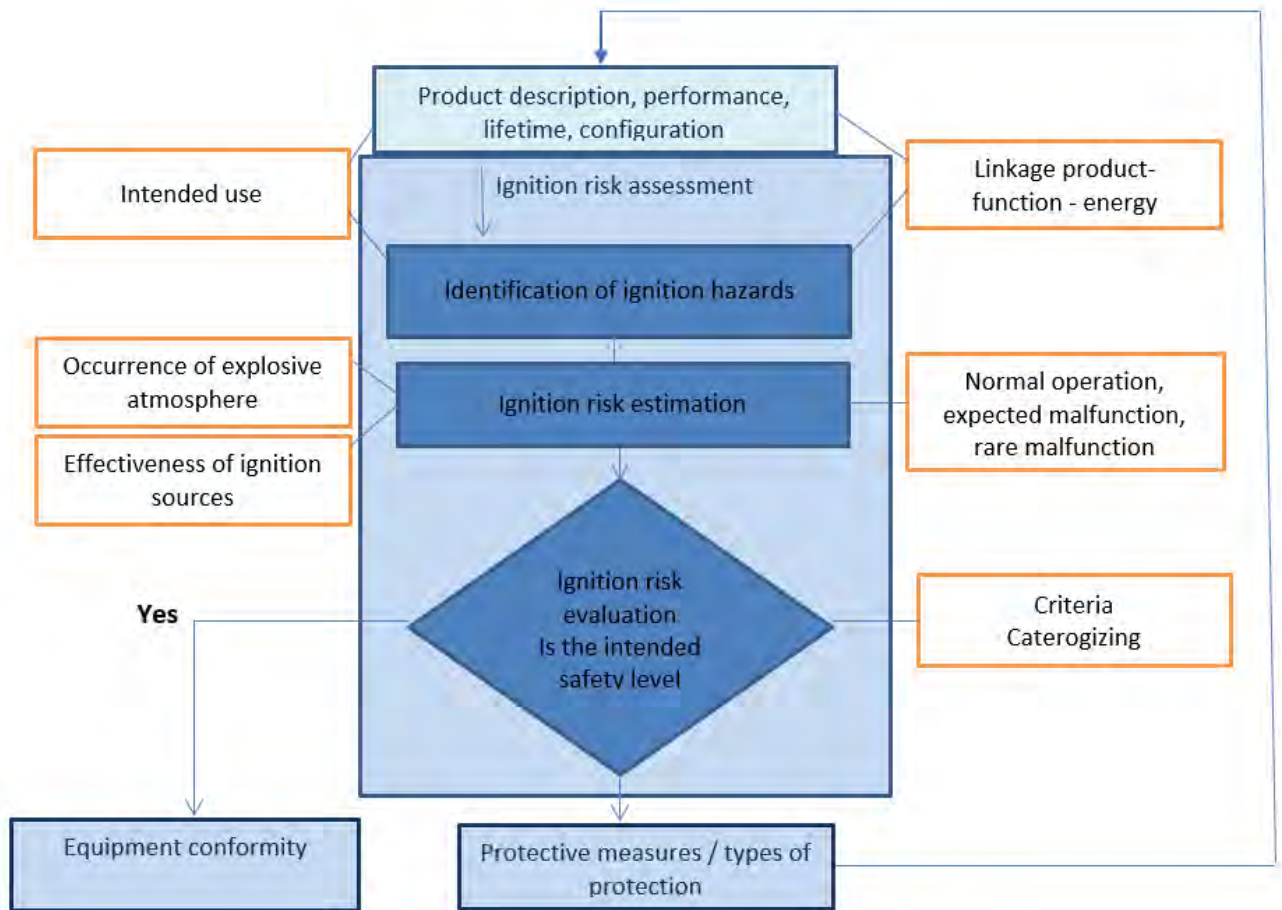
To meet the requirements of Directive 2014/34/EU it is necessary to conduct a risk assessment process. According to Annex II, 1.0.1 manufacturers are under an obligation to design equipment and protective systems from the point of view of integrated explosion safety. Integrated explosion safety is conceived to prevent the formation of explosive atmospheres as well as sources of ignition and, should an explosion nevertheless occur, to halt it immediately and / or to limit its effects. In this connection, the manufacturer must take measures with respect to the risks of explosion. However, in most cases he will not be in the position to understand the possible extent of the adverse consequences of an explosion (as part of the overall explosion risk) since this is solely dependent on the particular circumstances at the users' premises. So, the manufacturer's risk assessment will in general be restricted to and be focused on the assessment of the **ignition hazard** (part of the explosion risk) or the explosion control function for a protective system and safety devices. In principle the risk assessment comprises of four steps: ignition hazard identification, ignition risk estimation, ignition risk evaluation and risk reduction option analysis.

The principles and guidelines for risk management defined in the ISO SR 31000:2010 can be applied to ignition risk assessment for design of equipment or component according to methodology for the risk assessment from SR EN 15198: 2008 (figure 1).

### **2.1 Ignition risk assessment method**

The ignition source related to the equipment is any possible source of ignition that is produced by the equipment in question, regardless of its ability to ignite. These are sometimes called "relevant ignition sources", however this term can lead to misinterpretation whether the ignition source is relevant in the sense of being present or in the sense of its ability to ignite or in the sense of its existence in equipment or not.

All ignition sources related to the equipment are considered in the ignition risk assessment to determine whether they are potential ignition sources or not. The potential ignition source is the ignition source related to the equipment that has the ability to ignite an explosive atmosphere (thus becoming efficient). The probability of becoming efficient determines the category of the equipment (they can appear in normal operation, in expected malfunction, in rare malfunction).



**Figure 1.** Ignition risk assessment for design of equipment or component.

The efficient source of ignition is the potential source of ignition that is capable of igniting the explosive atmosphere if taken into consideration when it occurs (i.e. in normal operation, in expected malfunction or in rare malfunction) which determines the intended category of equipment. For example, frictional heating that can be caused by a bearing is a possible source of ignition. This is an ignition source related to the equipment if the equipment includes a bearing. If the energy that can be produced by friction in the bearing is able to ignite an explosive atmosphere, then this is a potential source of ignition. Whether this potential ignition source is effective or not depends on the probability of its occurrence in a given situation (e.g. after loss of lubrication). Figure 2 shows the relationship between the ignition sources defined above.

The equipment must be subjected to a documented ignition risk assessment to identify all potential sources of ignition that may occur during normal operation, in the event of an expected malfunction and in the event of a rare malfunction. Then, depending on the equipment's intended EPL, an attenuation of each of these potential ignition sources may be applied to minimize the likelihood that they will become actual ignition sources. Depending on the expected EPL (Ma or Mb), all potential ignition sources must be considered. Ignition sources caused by improper use, which can be reasonably anticipated, must also be considered.

The sources of ignition whose risk of becoming real remains present must also be listed, although the equipment has been designed to cut off its power supply in the event of an explosive atmosphere. The assessment must indicate the means used to minimize the likelihood of ignition. These means may be in accordance with this standard or with the standards relating to the specific types of protection.

The Directives sets out the mandatory essential health and safety requirements (EHSRs) that products placed on the EU market must fulfil, and the procedures for assessing their conformity.

Detailed technical solutions for complying with these EHSRs are given in European harmonized standards. Application of harmonized standards remains voluntary, but confers a presumption of conformity with the EHSRs they cover.

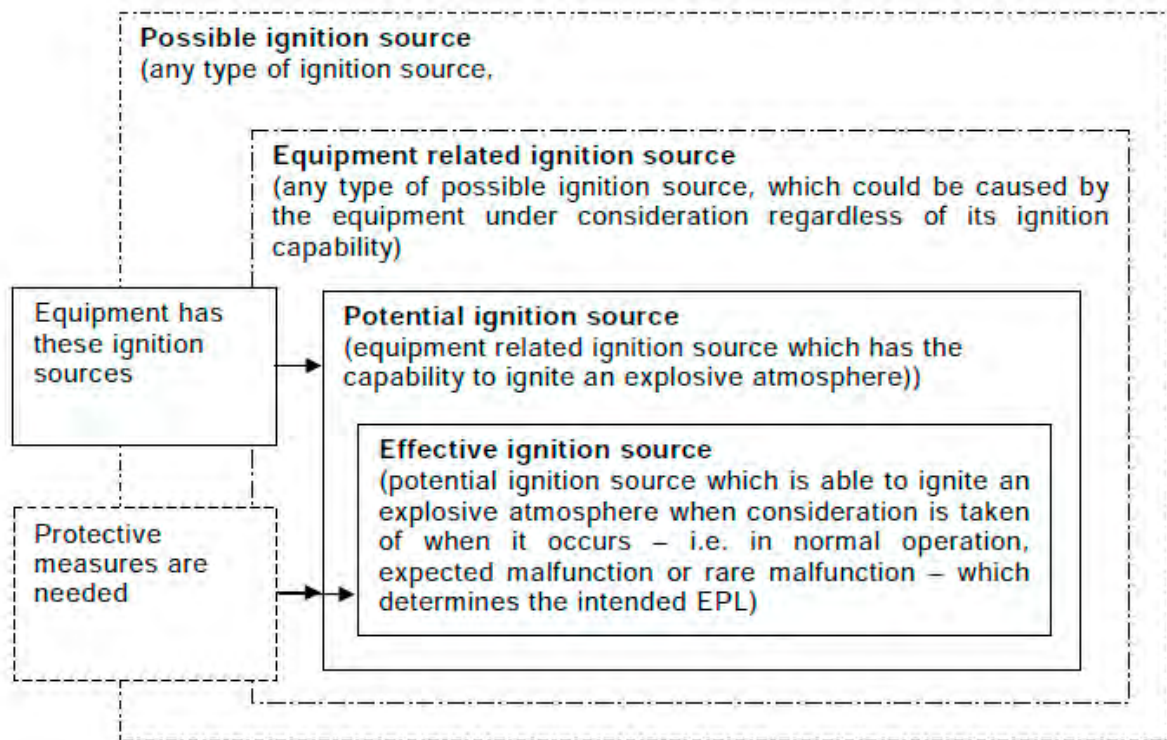


Fig. 2 - The relationship between the types of ignition sources existing in the evaluation process

### 3. Results

The technical requirements applicable to mechanical equipment are given in the standards: EN ISO 80079-36 and EN ISO 80079-37, and those for equipment in the mining industry in SR EN ISO 80079-38. In order to assess the conformity of mechanical equipment with the technical requirements of those standards, a series of specific tests are required to equipment intended for use in potentially explosive atmospheres. Frequently the standards do not fully cover the test methods applicable to the assessment of the risk of ignition from various sources of ignition. From the statistics registered both in the mining activity and in the other surface industries, there is a significant share of ignition sources such as mechanical sparks and hot surfaces generated by phenomena such as impact or friction between the component parts of the equipment.

Considering the danger of explosion present in firedamp mines as well as in other industries, for equipment made of unprotected light alloys, a series of specific regulations (norms and standards) have been developed that specify a series of requirements to limit the occurrence of sources of efficient ignitions that are not harmonized internationally, such as the case of ignition sources generated by impact and friction. In our country the tests are provided in the national standard STAS 10449-86. The test methodology for explosion protection materials (friction test and impact test in explosive air / gas mixtures) intended for use in potentially explosive atmospheres consists of modeling on special laboratory stands where the tests take place in different explosive air mixtures.

#### 3.1 Friction test

The friction test for the acceptance of spark arrestor materials intended for use in potentially explosive atmospheres is carried out in laboratory conditions and consists in simulating on special stands the process of forming sparks generated by accidental or technological friction in explosive gas mixtures. - figure 3.



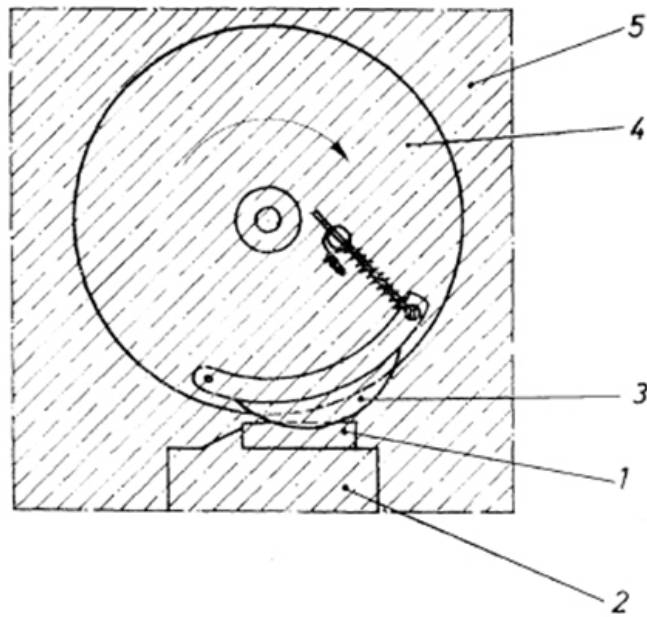


Figure 3 - Special stand for friction test

Legend:

- 1 - test plate;
- 2 - mobile support;
- 3 - test specimen;
- 4 - rotating disc;
- 5 - explosion chamber (the outer wall is open and covered with plastic foil, to allow the release of the explosion pressure) to achieve the test environment (explosive mixture).

### 3.2 Impact test

The impact test is performed in laboratory conditions and consists in simulating on special stands the process of forming sparks generated by accidental or technological impacts. The simulation is performed on a special test stand, in which an impact is generated between a rusty plate inclined at 35° to the vertical and the test sample.

The impact energy is determined with the relation  $E = m \times g \times h$ , [J], which  $m$  is the falling mass in [kg], the  $g$ -gravitational acceleration [ $m/s^2$ ] and  $h$  is the falling height [m]. The shape of the weight is chosen depending on the destination of the material used in the construction of the equipment. For the impact test, the parameters  $m$  and  $h$  shall be determined by mutual agreement between the parties, or in accordance with the applicable regulations (figure 4).

In both cases, the friction or impact test, when testing the materials for the equipment intended for use in mines with firedamp, in the test chambers an explosive mixture of air with 6.5% CH<sub>4</sub> is made with the help of a complex installation (figure 5). The accuracy of making explosive mixtures is important in expressing the results.

The objective of the two methods focuses on potential sources of ignition such as mechanical. From light metals, in certain presumptive situations, sparks may be obtained by impact or friction, which may ignite explosive mixtures of gas-air or dust-air. Protected or unprotected light metal surfaces must be checked for protection against the formation (production) of mechanical sparks capable of ignition.

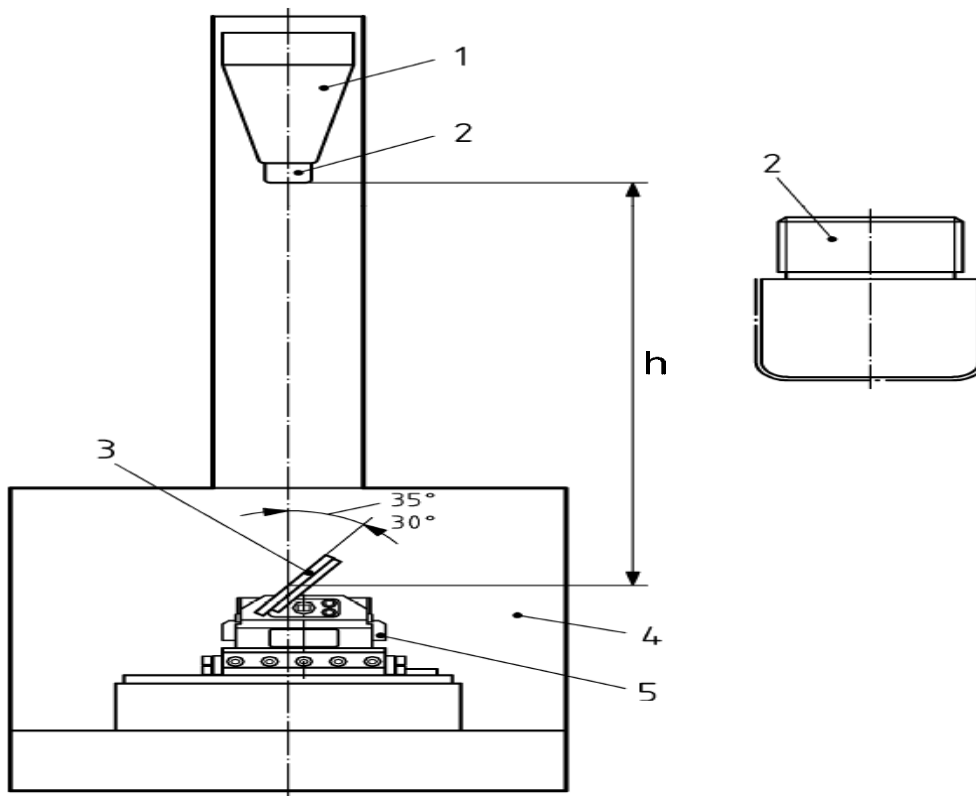


Fig. 4. Assembly for testing non-sparking materials at single impact in explosive mixture

**Legend:**

- 1 – weight/mass required to obtain the impact energy;
- 2 - test sample/specimen;
- 3 - rusty steel plate or another test sample/specimen;
- 4 - test chamber;
- 5 - device for longitudinal / transverse movement and adjustment of the impact angle of the rusted steel plate;
- h – drop height

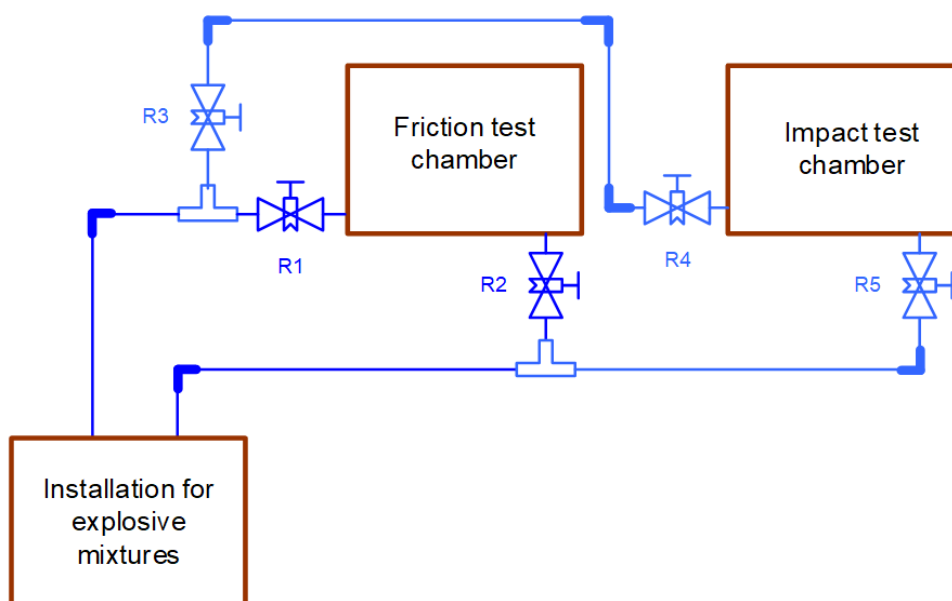


Fig.5 – Schematic diagram of the installation for the production of the explosive mixture



The two methods provide the physical tools for analyzing the capacity to produce mechanical sparks, in order to evaluate the ignition sources specific to mechanical equipment. This stage of evaluation of ignition sources has a special importance in the process of assessing the conformity of non-electrical equipment and implicitly in identifying occupational safety and health risks.

#### **4. Conclusions**

Assessment of the ignition risk, when using equipment and components intended for underground use, is particularly important for ensuring workers' health and safety. According to the legislation in force, the responsibility for risk assessment and adopting the required protective measures in order to ensure an acceptable safety level is responsibility of the equipment manufacturers and users.

The conformity assessment methods of non-electrical equipment intended for underground use presented in the paper, have as main purpose to increase the level of safety and protection of workers in the mining industry. The applied measures must make the ignition sources harmless or shall reduce the occurrence probability of the ignition sources.

The two methods provide the physical tools for analyzing the capacity to produce mechanical sparks, in order to evaluate the ignition sources specific to mechanical equipment. This stage of evaluation of ignition sources has a special importance in the process of evaluating the compliance of non-electrical equipment with the requirements of the ATEX Directive and implicitly in identifying occupational safety and health risks.

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