

Explosion risk assessment for mining belt conveyors

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Abstract. As science and technology have developed, new types of equipment and installations with increased reliability and safety have emerged, with belt conveyors now available with many more components, highly sophisticated electrical controls and safety devices, as well as stronger and more durable belts. New technologies create new challenges in assessing explosion risks when installed in environments with potentially explosive atmospheres, such as in firedamp mines. The challenges are greater in the case of old installations that are being modernized to meet current explosion safety requirements.

The paper presents a series of aspects regarding the assessment of the risk of explosions in mining belt conveyors, an assessment that employers must make, according to GD 1049/2006 (European Directive 92/104/EEC). The assessment must be based on compliance with the requirements of the ATEX Directive 2014/34/EU and the applicable standards.

For surface installations, there is the draft standard IEC TS 60079-46 used for risk assessment but which does not apply to mine equipment assemblies susceptible to firedamp (group I applications). For mining installations there is no specific evaluation method or guide, therefore evaluators must generate their own evaluation method based on the norms and standards in force such as SR EN 1127-2: 2014, SR EN 60079-0:2018+AC, SR EN ISO 80079-36:2016, SR EN ISO 80079-37:2016, SR EN ISO/IEC 80079-38: 2017 (SR EN 1710+A1:2008 /AC:2011).

1 Introduction

In different processes related to combustible materials in powder form (production, transport and storage) where the explosion risk is present (by explosive atmospheres of air-dust), ignition sources can become effective, some of them generated at the company's own facilities. Since explosion effects can produce even human casualties and serious material deterioration, assessment of the explosion risk and the adoption of proper technical measures by manufacturers and appropriate technical and organisatoric measures by the users of installations to mitigate the explosion risk due to the ignition of explosive atmospheres is considered to be of high importance.

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In the paper are provided technical information related to risk analysis for belt conveyors transporting bulk materials. Also, are provided procedural and organisatoric measures referring to the European legislative framework and standards considered to be applicable.

Two European directives (known as ATEX directives) are regulating the placing on the EU market of explosion-proof products on one side (Directive 2014/34/EU [1]) and the provisions to be adopted for the safe use of installations and the explosion risk, on the other side (Directive 1999/92/EC [2]). Some aspects related to the borderline situations in which the two mentioned directives are applied, are also presented in the paper, considering the case of equipment assemblies that must be evaluated considering the provisions of [1] for placing on the EU market and of installations that are assembled by the user under his responsibility (using ATEX compliant equipment) and that must be assessed by the user considering the requirements of [2].

2 Risk assessment methods and/or techniques

The manufacturers of ATEX compliant products are required to carry out a risk assessment to meet the requirements of Directive 2014/34/EU. Integrated explosion safety must be considered by the manufactureres in the design process of equipment and protective systems (taking into account the provisions of Annex II, 1.0.1). Integrated explosion safety considers the following aspects: prevention of explosive atmospheres to be formed, ignition sources to becom efficient and, if the explosion is still produced, to stop it immediately and/or to limit the specific explosion effects. Considering the before mentioned aspects, the manufacturer are obliged to take all the required measures to minimize the explosion risks. But still, in many cases, the manufacturer will not be able to consider all the negative consequences and possible extent in case of explosions (that must be considered as part of the overall explosion risk), as this depends only on the specific conditions that occur at the users' premises. Therefore, the risk assessment that is made by the manufacturer will generally consider only the ignition hazard and focus on it (as a part of the explosion risk assessment). In case of protective systems and safety devices the explosion control function will be envisaged in the explosion risk assessment.

Risk assessment, according to SR EN 15198, comprises four stages: hazard identification, risk estimation, risk evaluation and risk reduction options analysis. [3]

The risk of explosion consists of two elements: the probability of damage occurring and the severity of the possible damage.

$$Risk = Likelihood \times Severity \quad (1)$$

To quantify the probability of an explosion to occur is usually very difficult, but its severity or consequences can be characterized in many cases. The consequences assessment (extent of the foreseeable ones) is not of high importance due to the fact that it is considered that explosions always will produce specific damage, ranging from significant material damage to human damage that may lead to death of persons.

The probability of an explosion (ignition risk) is determined by the likelihood for an explosive atmosphere to occur in the same place and at the same time as the occurrence of an effective ignition source.

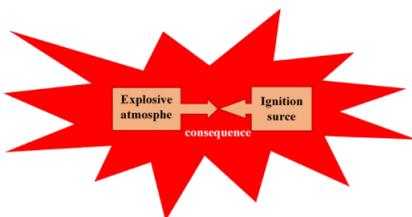


Fig. 1. Factors considered for explosion risk assessment

ISO SR 31000:2010 specifies the principles that can be applied to the analysis of the ignition risk. Also, this standard provides a guidelines for risk management defined for the construction of equipment or component parts, as provided for in the risk assessment procedure in SR EN 15198:2008 (Fig. 2). [3]

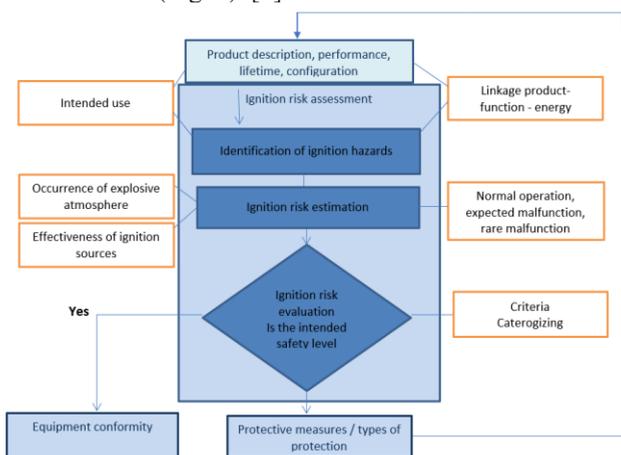


Fig. 2. Ignition risk assessment for design of equipment or component

3 Principles in explosion prevention and protection – eliminating or minimizing the risk of explosion

The situation of the simultaneous presence of an explosive atmosphere and an effective ignition source, as well as the foreseeable effects of an explosion, leads directly to the three basic principles in explosion prevention and protection: [4,5]

a) prevention:

- avoiding explosive atmospheres by modification of the flammable substance concentration so as to be outside the explosion concentration limits or by changing the oxygen amount so that it is below the limiting concentration (LOC);
- avoiding all possible effective sources of ignition through appropriate design of devices, protective systems and component parts all;
- de-energizing equipment containing ignition sources when the flammable substance has an explosive concentration.

b) protection:

- limiting the effects of the explosion to an acceptable level through constructive protective measures.

The elimination or mitigation of risks is achieved by applying one or more of the prevention and protection principles mentioned above. The first option must always be to avoid the explosive atmosphere. The greater the probability of an explosive atmosphere, the

greater the extent of measures taken against effective ignition sources, and vice versa. To enable the selection of appropriate precautionary measures, an explosion safety concept must be developed for each individual case.

4 Belt conveyors – ignition risk assessment

A belt conveyor is a type of conveying machine that transports bulk materials, such as coal, from one place to another continuously. Belt conveyors operating in potentially explosive atmospheres, such as in the mining industry, must be designed, assembled and maintained so that they do not generate sources of initiation of the explosive atmosphere.

The belt conveyor machine is composed of a conveyor frame, a conveyor belt, a conveyor pulley, conveyor rollers, tensioning devices, drive unit and other components, etc. It can be located in potentially explosive atmospheres generated by external sources or by the flammable materials being transported.

From a construction point of view, belt conveyors can be closed or open.

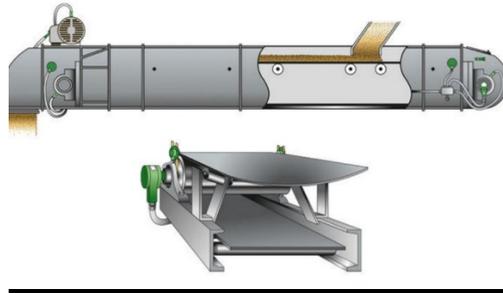


Fig. 3. Belt conveyors closed and open [6]

Conveyor belts are equipped with a wide range of sensors for monitoring bearing temperature, speed or movement, belt alignment and level/shutter indication, which are connected to hazard monitoring systems.

Protective devices refer to the detection of dangerous situations and the automatic alarming or stopping of the conveyor. Where appropriate, according to the provisions of SR EN 620, conveyor belts may be equipped with the following types of automatic fault detection devices to reduce hazards:

- band-gap detectors
- blockage/overload detection devices for conveyors, hoppers, chutes
- shaft rotation detectors
- lane speed monitoring
- thermal detectors
- height and/or width detectors

Belt conveyors are made by assembling equipment and components available on the market. Most electrical or non-electrical equipment is certified as an individual piece of equipment, e.g. motor, switchboard, gearbox, couplings, pump, etc., and meets its own marking requirements. This certification, however, does not refer to the interconnection of this equipment via cables or to the machine's electrical power system as a unitary entity. Equipment and components, including their interconnections, must be evaluated from the point of view of flash point. Therefore, new and old (already installed) belt conveyors intended for transporting coal in a coal mine with a potentially explosive atmosphere of coal dust and/or firedamp must be assessed for compliance with ATEX requirements.

There are two situations: the assessment by the manufacturer and the assessment by the end user of belt conveyors regarding the risk of initiating a potentially explosive atmosphere.

4.1 Belt conveyor evaluation by manufacturer

When the conveyor is placed on the market by a manufacturer, as a whole or as an assembly of several components, he must carry out the risk analysis at initiation and will assess the product's compliance with the ATEX requirements. A conveyor assessment procedure shall be developed to assess the equipment assembly, as defined in IEC TS 60079-46, the prefabricated combination of Ex equipment, together with other parts as required, which are electrically or mechanically interconnected, which are pre-assembled before being put into service at the end-user site, and which can be disassembled and then reassembled at the end-user site. [7]

Risk assessment limited to the assessment of ignition risk is part of the product's compliance with the Essential Health and Safety Requirements (EHSR) of [1]. The technical requirements for compliance with these EHSRs are set out in harmonised European standards. The application of harmonised standards offers a presumption related to the conformity of the equipment (manufactured considering the provisions of those technical standards) with the essential requirements.

Integrated explosion safety must be considered by the manufactureres in the design process of equipment and protective systems (taking into account the provisions of Annex II, 1.0.1 of [1]). Integrated explosion safety is designed to prevent explosive atmospheres to be formed and, also, considers the ignition sources. Ignition sources shall be assessed [4, 5].

The assessment of the belt conveyor's compliance with the ESHR of the ATEX Directive involves an explosion risk analysis that must take into account potential ignition sources that may occur during normal operation, but also in the event of foreseeable faults and rare faults, depending on the intended use. "Intended use" represents the case when a product is placed by the manufacturer in a specific equipment group and category (according the provision of [1]). Also, providing all the information necessary for the safe operation of a system, device or protective component represents also an iinteded use of a specific equipment.

According [1] equipment is divided in 2 groups: Group I (mines) and Group II (surface). Group I (mines) is divided in 2 categories, as shown in table 1. In order to chose the appropriate assessment procedure related to the conformity of the product, the manufacturer must first determine in which group and category it's product will fall, based on the prevention of ignition sources under normal operating or fault conditions.

Table 1. Correspondence of equipment group

	Category of Equipment	Atmosphere	Level of Protection	Performance of Protection	Condition of Operation
GROUP I (MINES)	M 1	Methane, dust	Very high	2 independent protection methods, or safe with 2 faults	Equipment remains energised and functioning
	M 2	Methane, dust	High	Suitable for normal operation and severe operating conditions	Equipment is de-energised

The conveyor is classified in the M2 ATEX category (EPL Mb equipment). Therefore, it is necessary to draw up an ignition hazard assessment report to be included in the technical file, in accordance with the requirements for EPL Mb equipment. This means that a high level of protection against ignition must be ensured, regardless of whether or not it is intended to be de-energized in the event of an explosive atmosphere.

The equipment assembly must be checked for compliance with the requirements of SR EN IEC 60079-0, SR EN ISO 80079-36 and SR EN ISO/IEC 80079-38, as applicable. [8,9,10]

Both electrical and non-electrical equipment, as well as the interconnection of electrical/non-electrical equipment, require an ignition hazard assessment.

It is therefore necessary that not only the equipment, but all its components, are examined by the manufacturer in accordance with a formally documented ignition risk assessment, which establishes and lists all possible ignition sources of the equipment, including the cables and the electrical supply system. Each ignition source, according to EN 1127-2, must be analyzed. The documentation must list the measures that must be introduced to prevent the occurrence of possible ignition sources.

All electrical and non-electrical components, equipment or devices that make up a belt conveyor have already been assessed for compliance with the requirements of the European Directive ATEX 2014/34/EU when they were placed on the market by their manufacturers.

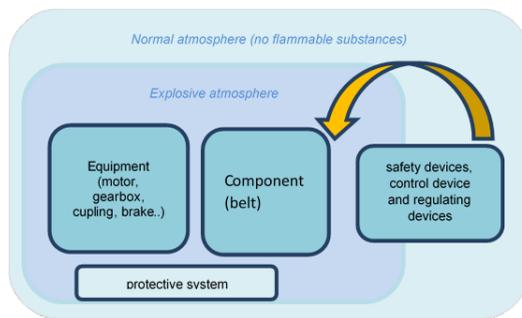


Fig. 4. Parts of belt conveyors comply with the Directive 2014/34/EU

An analysis of non-electrical equipment in a belt conveyor shows the following possible sources of ignition during normal operation: increased bearing temperature, frictional heat from moving parts inside the gearbox, frictional heat from the brakes, dust entering the brake housing, frictional heat from the gearbox guide rollers, dust deposits on the gearbox, static electricity discharge, surface temperature of all moving parts.

Initiation sources can also occur in the event of a foreseeable failure, such as: bearing failure due to loss of lubrication, belt rubbing against spilled product, stones or metal fragments entering the gearbox, unacceptable loss of oil from the gearbox, brakes left on too long after the drive motor has started, brake disengagement fails, clutch slippage, belt guide roller jamming and rubbing against the moving conveyor belt, conveyor belt slipping on the drive drum due to loss of tension or belt jamming, belt driven at excessive speed, friction between the belt and fixed parts, moving parts close together, clearance filled with dust.

ISO/IEC 80079-38 specifies requirements for the constructional characteristics of equipment and components which may be an individual element or may form an assembly, to enable their use in mines or parts of mines, susceptible to explosive atmospheres of combustible dust and/or firedamp. Design solutions for preventing ignition sources refer to the selection of appropriate equipment/components and materials or to ignition source control, where mechanical or electrical devices (safety devices) are used in conjunction with non-electrical equipment to manually or automatically reduce the likelihood that a potential ignition source will become an actual ignition source.

Safety devices are devices intended for use inside or outside the explosive atmosphere, but necessary for or contributing to the safe operation of equipment and protective systems with regard to explosion risks. Since malfunction of any of the sensor/actuator control devices

may result in the appropriate ignition control measure not being applied, they must be considered as parts of the safety equipment that must be protected against failure.

The conveyor belt according to [1] is a "U" shaped component. It must be incorporated into an equipment by its manufacturer/user, in accordance with the manufacturer's instructions. The selection of conveyor belts is based on a risk analysis of the possibility of initiating explosive mixtures by intrinsic ignition sources, which refers to electrostatic charging and combustion and flame propagation due to overheating by friction or other ignition sources. The protective performances of conveyor belts are given in specific standards (SR EN 14973: 2008) which refer to several classes/categories of conveyor belts. For the integration of the conveyor belt into a conveyor belt that must provide a certain level of protection appropriate to the intended use in each case, some additional protective measures may be necessary. [11,12]

4.2 End-user assessment of ignition risk

When the conveyor is manufactured or upgraded by the user by assembling its components, the responsibility for assessing the ignition risk lies with the user, who must assume the obligations and responsibilities of the manufacturer in the safety and health document (see Explosion Protection Document - Directive 1999/92/EC), as applicable. To fulfill the obligations set forth in [2], the employer (end user) must ensure the preparation and updating of a document called an Explosion Protection Document (EPD). The key element of DPE is the explosion risk assessment. Users only need to classify their hazardous areas according to SR EN 60079-10-2 and then choose the equipment accordingly. Subsequently, the installation as a whole will be assessed for possible ignition sources. The applicable methods for assessment must take into account: the sensitivity of the explosive atmosphere (the characteristics of the substances), the probability of its occurrence and the probability of the occurrence of the ignition source. [13,14]

5 Aspects regarding the evaluation of the use of belt conveyors in firedamp underground mines

New and old (already installed) belt conveyors intended for transporting coal in a coal mine with a potentially explosive atmosphere of coal dust and/or firedamp must be assessed for compliance with ATEX requirements.

The manufacturer must build the conveyor to meet the requirements for EPL Mb equipment (ATEX category M2). Therefore, it is necessary to draw up an ignition hazard assessment report to be included in the technical file, in accordance with the requirements for EPL Mb equipment. This means that a high level of protection against ignition must be ensured, regardless of whether or not it is intended to be de-energized in the event of an explosive atmosphere.

The conveyor must be properly assessed for ignition risk to detect all possible ignition sources that could arise. Then, according to the specified EPL of the conveyor, mitigation can be applied to these potential ignition sources to minimize the chance that they will become actual ignition sources. According to the specified EPL (Ma or Mb), all potential ignition sources must be considered.

It is also necessary to list the ignition sources whose risk of becoming real remains present, although the equipment has been designed to cut off the power supply in the event of an explosive atmosphere. The assessment must indicate the means used to minimize the probability of ignition. These means must comply with the standards relating to the specific types of protection.

Given the explosion hazard 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 for limiting the occurrence of efficient ignition sources, which are not harmonized at international level, such as the case of ignition sources generated by impact and friction. In our country, the tests are provided for in the national standard STAS 10449-86. The testing methodology for spark-proof protective materials (friction test and impact test in explosive air/gas mixtures) intended for use in explosive atmospheres consists of modeling on special laboratory stands where tests are performed in various explosive air/gas mixtures.

6 Conclusions

Determining the ignition hazard when using equipment and parts intended for use in mining is particularly important for ensuring the health and safety of workers. According to the legislation in force, the responsibility for determining the risks and establishing the necessary protective measures lies with the manufacturers and users of equipment. For this reason, belt conveyors used in potentially explosive atmospheres must undergo rigorous, well-documented hazard assessments to uncover all potential ignition sources and take the necessary measures to prevent these sources from becoming active.

The assessment of the ignition risk of belt conveyors, as an assembly of equipment, must take into account the requirements of the standards IEC TS 60079-46, SR EN IEC 60079-0, SR EN 60079-14, as applicable.

The conformity analysis procedures for non-electrical devices intended for underground use, presented in the paper, have as their main purpose increasing the level of safety and protection of workers in the mining industry. The measures applied must render ignition sources harmless or reduce the likelihood of ignition sources occurring.

The 2 methods provide the physical tools to analyze the capacity to produce mechanical sparks, in order to evaluate the ignition sources specific to mechanical equipment. This stage of assessing ignition sources is of particular importance in the process of assessing the compliance of non-electrical equipment with the requirements of the ATEX Directive and implicitly in identifying occupational health and safety risks.

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References

1. Directive 2014/34/EU of the European Parliament and the Council of 26 February 2014 on the harmonization of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres, Official Journal of the European Union. L 96/314, 29.3.2014
2. Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres. Official Journal No. L 023, 2000-01-28, 57-64
3. SR EN 15198: 2008 Methodology for the risk assessment of non-electrical equipment and components for intended use in potentially explosive atmospheres

4. SR EN 1127-1:2019 Explosive atmospheres. Explosion prevention and protection. Basic concepts and methodology
5. SR EN 1127-2:2014 Explosive atmospheres. Explosion prevention and protection Basic concepts and methodology for mining.
6. Hazard Monitoring Equipment Selection, Installation and Maintenance, 4B Components Ltd, 4B Components, Ltd. 2022
7. IEC TS 60079-46 Explosive atmospheres - Part 46: Equipment assemblies.
8. SR EN IEC 60079-0:2018/AC:2020 Explosive atmospheres - Part 0: Equipment - General requirements
9. SR EN ISO 80079-36:2016 + AC 2020 Explosive atmospheres — Part 36: Non-electrical equipment for use in explosive atmospheres — Basic methods and requirements
10. SR EN ISO/IEC 80079-38:2016 Explosive atmospheres - Part 38: Equipment and components in explosive atmospheres in underground mines (ISO/IEC 80079-38:2016)
11. Păun F.A.: Project Program NUCLEU „Development of research facilities regarding the risk or the probable frequency of occurrence of dangerous phenomena depending on the specific circumstances of applications in atmospheres with danger of explosion of conveyor belts (DFCBT)”, 2010-2011
Păun F.A.: Project Program NUCLEU, Technology for testing small-scale combustion conveyor belts according to European standard”, 2012
12. SR EN 14973:2016 Conveyor belts for use in underground installations - Electrical and flammability safety requirements.
13. SR EN 60079-10-2 Explosive atmospheres - Part 10-2: Classification of areas - Combustible dust atmospheres
14. SR EN 12882:2016 Conveyor belts for general purpose use. Electrical and flammability safety requirements