Application of flammability testing methods for conveyor belts intended for use in potentially explosive atmospheres in order to select suitable types for field application

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Abstract. The conveyor belts are widely used and can be found, for example, in the underground and surface mining industry as well as in other industries involving the transport of various products, materials, etc.
The need to ensure the transport of various products, materials, involves the use of conveyor belts in normal environments as well as in environments with a potentially explosive atmosphere.
When used in potentially explosive atmospheres, conveyor belts shall not be sources of ignition for the explosive atmospheres generated by gases, vapors, flammable mists and/or combustible dusts in the mixture with the air.
This involves the use of conveyor belts in a particular construction, compliance with the applicable essential safety and health requirements as well as granting a special attention to the identification/selection of types suitable for the specific field application.
The purpose of the paper is to highlight the importance of testing by accredited laboratory tests, the flammability properties of conveyor belts intended for use in potentially explosive atmospheres, in order to easily identify/select, by end users, the types of conveyor belts adequate for specific application.

1 Introduction

The need to ensure the transport of various materials, products, etc., has led to the occurrence, realization, development and use in practice of the transport systems, which include conveyors, which depending on the basic component with effective role in transporting a material, product could be with scrapers or belt.

Given the diversity of materials, products transported, conveyors, both with scrapers and belts can be found in most industries. Therefore, conveyors can be found both in unclassified environments also known as normal environments and in environments with explosive atmospheres, environments where there is a risk of explosion.

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In practice, there are quite a lot of applications, when conveyors are used to transport materials, products that together with oxygen generate explosive mixtures that in the presence of an ignition source can lead to explosion and/or fire, for example the following can be mentioned: transport of cereals, transport of useful mineral substances, transport of materials resulting from wood processing, etc.

When used in potentially explosive atmospheres, in order to reduce the risk of explosion, both the equipment and its components (conveyor - conveyor belt) must be of special construction. This construction assumes that the conveyor or conveyor belt does not generate electrical sparks, mechanical sparks of impact and friction, static electricity, overheated surfaces, or other sources of energy that could initiate the explosion.

If we refer to the conveyor belt, as a component part of the conveyor, it being non-metallic, made of rubber or polymers, with or without inserts, during operation it can accumulate electrostatic charges, thus acquiring an electrostatic potential. On the other hand, due to the blockage of the belt and the excessive friction between it and the drive drum of the conveyor, high temperatures can develop which lead to the ignition of the conveyor belt and then to its burning.

All these phenomena, which are strictly related to the operation of the conveyor belts, are sources of ignition for potentially explosive atmospheres, thus manifesting a significant influence on the level of security in the technological spaces in which they operate.

Aspects related to the properties of conveyor belts used in environments with danger of potentially explosive atmospheres, namely flammability, resistance to friction on the drum, electrostatic charging, respectively the development of test methods for the laboratory determination of these properties have been the subject of research topics carried out within the NUCLEU program. (Development of research facilities on the risk or probable frequency occurrence of hazardous phenomena depending on the specific circumstances of applications in atmospheres with a potential for explosion of conveyor belts (DFCBT), NUCLEU Program Project, 2010-2011).

In the context of the theoretical aspects mentioned above, ensuring a level of safety and health, as high as possible, involves the use of conveyor belts that during their operation do not generate ignition sources for explosive atmospheres.

To ensure this desideratum, it is necessary, in a first stage, to determine by accredited laboratory tests the properties of the conveyor belts on flammability, resistance to friction on the drum, electrostatic charging with electrostatic charges, then based on the results obtained, selection of suitable conveyor belts for the application specific.

2 Methods for determining the flammability of conveyor belts

2.1 Test to spread fire on a medium scale

2.1.1 Principle of the test method

The test specimen from the conveyor belt to be tested shall be placed in a combustion chamber containing an enclosure made of a refractory material with thickness of 25 mm and then placed on a metal support (trestle).

Place a burner with six nozzles inclined at an angle of 45º under the test specimen, ignite and keep the flame for 50 minutes. At the end of the flame exposure period, examine the appearance of the test specimen remaining after combustion, determine the increase of temperature and the length of the conveyor belt consumed during the test. [1], [2], [3]

2.1.2 Description of the stand for test to spread fire on a medium scale

Principle scheme of the stand for test to spread fire on a medium scale for the purpose of testing in the laboratory of conveyor belts, intended for use in potentially explosive atmospheres, as a component of transport installations, in order to assess compliance with the applicable essential safety requirements according to Directive 2014/34 / EU - ATEx, is shown in Figure 1.

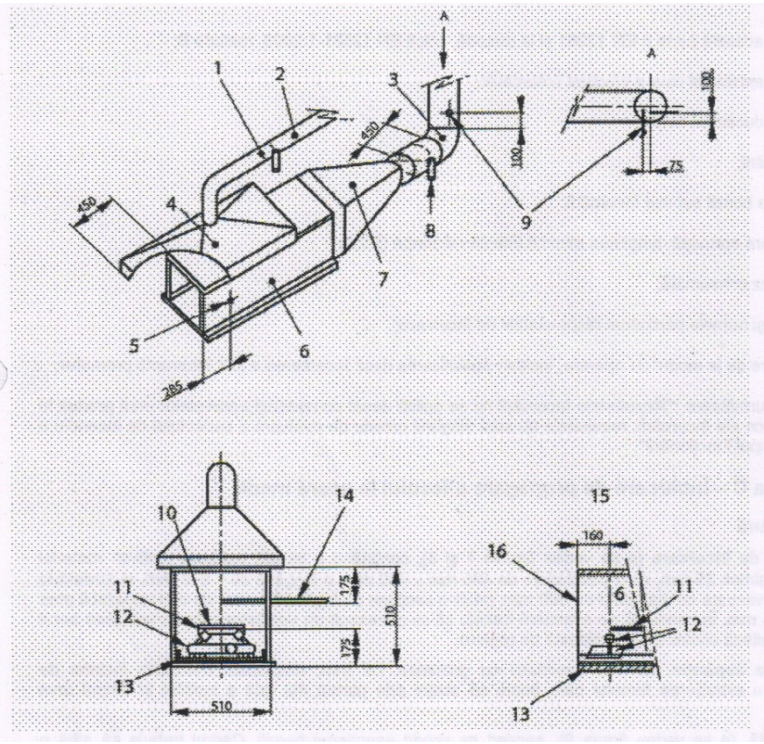

Fig. 1. Principle scheme of the stand for test to spread fire on a medium scale

The test stand shown in Figure 1 consist by:

- exhaust control flap (1)
- exhaust pipe, diameter 150 mm (2)
- exhaust pipe, diameter 300 mm (3)
- exhaust hood (4)
- anemometer location (5)
- test enclosure (6)
- connecting tube (7)
- exhaust control flap (8)
- thermocouple (9)
- specimen (10)
- trestle (11)
- burner (12)
- waste collection tray (13)
- anemometer location (14)
- exhaust hood not presented (15)
- front face (16)

2.2 Flame resistance test

2.2.1 Principle of the test method

A test specimen cut from the conveyor belt is suspended vertically above the flame of a burner for a specified time after which the burner is withdrawn. Measure the time of residual

flame and residual incandescence. Any recurrence of the flame shall be noted when the specimen is subsequently subjected to an air current. [2], [3], [4], [5]

2.2.2 Description of the flame resistance test stand

Principle scheme of the flame resistance test stand required for laboratory testing of conveyor belts, of which destination is the environments with explosion danger, is shown in Figure 2.

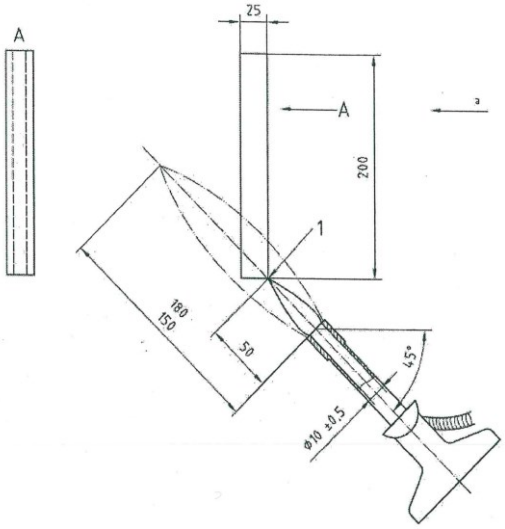

Fig. 2. Principle scheme of a gas burner and a test piece during the flame resistance test

The composition of the test stand also includes a thermocouple (1) necessary for measuring the flame temperature, [a] representing the direction of the air flow to which the test piece is exposed after removing the burner.

2.3 Flammability test with a single burner on a length of 2 m

2.3.1 Principle of the test method

The conveyor belt specimen is introduced into a combustion gallery, after which it is placed on a support type boiler grate. Place a burner under the test specimen, whose flame remains in contact with the surface of the test specimen for 10 minutes. After 10 minutes of exposure to the flame, examine the appearance of the remaining test specimen after combustion. Measure and record the length of the portion of conveyor belt that remained intact over the entire width of the specimen. [2], [3], [4], [5]

2.3.2 Description of the stand for flammability test with a single burner on a length of 2 m

The components of the stand for the flammability test with a single burner on a length of 2 m, necessary for testing in laboratory of the conveyor belts, to be used in potentially explosive atmospheres, are shown in Figure 3.

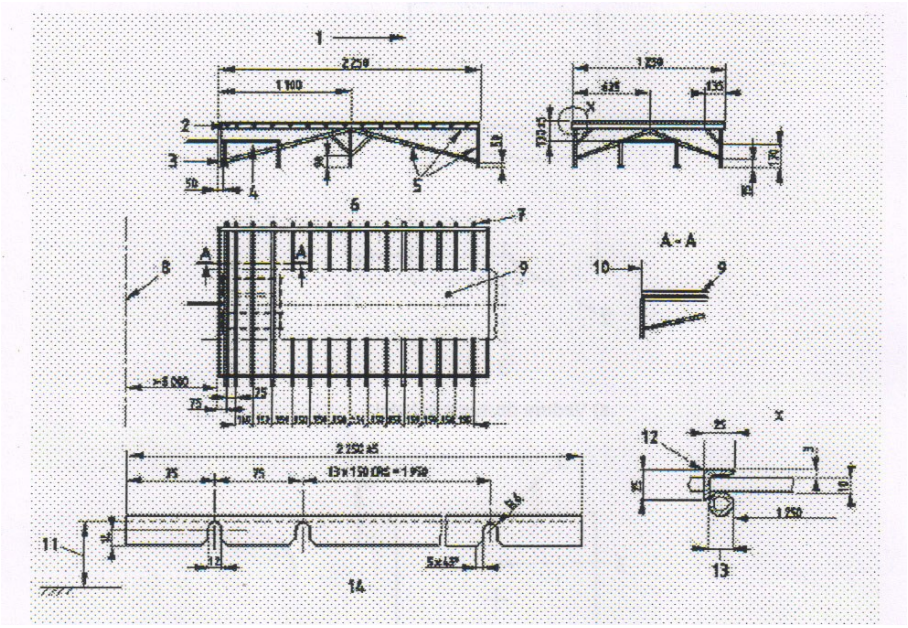

Fig. 3. Propane burner trestle with presentation of burner and test specimen positions

The components of the test stand and the details of execution are as follows:

- the direction of ventilation (1)
- additional bar (2)
- end protected with cross tie (3)
- propane burner (4)
- DN15 heavy series pipe (5)
- trestle detail (6)
- austenitic chrome / nickel steel bars (7)
- gallery entrance (8)
- specimen (9)
- test specimen edge (10)
- distance of 350 mm from the flow line (11)
- holding bars (12)
- DN15 heavy series trestle (13)
- cutting-out detail (14)

To the above-mentioned components are added the combustion gallery with a cross-section of maximum 6 m^2, an anemometer and thermocouple for measuring the temperature of the air flowing through the combustion gallery.

2.4 Flammability test with double burner

2.4.1 Principle of the test method

The conveyor belt specimen is introduced into a combustion gallery, after which it is placed on a support type boiler grate. Place a burner under the test piece, whose flame remains in contact with the surface of the test specimen for 10 minutes. After 10 minutes of exposure to the flame, examine the appearance of the remaining test specimen after combustion. Measure and record the length of the portion of conveyor belt that remained intact over the entire width of the specimen. [2], [3], [4], [5]

2.4.2 Description of the stand for flammability test with double burner

The components of the double burner flammability test stand required for testing in laboratory of conveyor belts intended for use in potentially explosive atmospheres are the same as those used in the case of the flammability test with a single burner on a length of 2 m, the difference being given by the construction of the burner, which is shown in Figure 4.

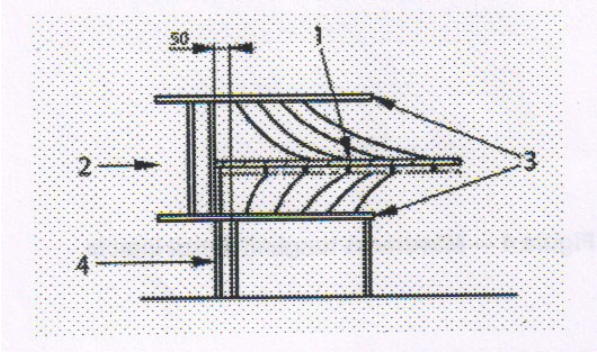

Fig. 4. The positions of the trestle, the double burner and the test specimen

Other elements and technical details are presented as follows:

- specimen (1)
- the direction of ventilation (2)
- double burner (3)
- trestle (4)

3 Assessment of conveyor belts in relation to safety requirements and the prevention of ignition risk of the explosive atmospheres

Conformity assessment of the conveyor belts intended for use in potentially explosive atmospheres, as a component of transport installations, shall be carried out in relation to the essential health and safety requirements set out in Directive 2014/34/EU - ATEx relating to equipment and protective systems intended for use in potentially explosive atmospheres [6].

As regards the requirements for the prevention of the ignition sources of explosive atmospheres, generated by conveyor belts during their operation, they are given in a series of standards with applicability at national and international level.

For conveyor belts for general use, the electrical safety and flammability protection requirements are given in the standard SR EN 12882:2016, while for conveyor belts for use in underground installations, the requirements for electrical safety and flammability are found in the standard SR EN 14973:2016.

According to the SR EN 12882:2016 standard, the conveyor belts are classified in categories 1, 2A, 2B, 3A, 3B, 4A, 4B, 5A, 5B and 5C, the electrical safety and flammability protection requirements applying for each category in part depending on the field of use of the conveyor belt respectively the application in which it's to be used.

Thus, the electrical safety requirements apply to all categories of conveyor belts, the safety requirements for protection against flammability apply to all categories except for category 1, and the safety requirements for the spread of a flame along a conveyor belt apply only for categories 4A, 4B, 5A, 5B and 5C.

In order to meet the electrical safety requirements respective in terms of the electrical conductivity, any conveyor belt for general use, regardless of its category, must have an electrical resistance of less than 300 MΩ.

With regard to the safety requirements relating to the flame protection of conveyor belts, they are considered to provide the flame protection required, if the total flame persistence times for a number of six samples tested do not exceed 45 seconds and no one individual test does not exceed 15 seconds.

If we refer to the safety requirements regarding the resistance to friction on the drum, in the case of the conveyor belts subjected to the test no one flame or incandescence must occur during the whole test or until the sample is broken whichever is the shorter of the two; for category 5C, in addition to those mentioned above, the temperature of the drum, which must not exceed 400 ºC at any time.

According to the standard SR EN 14973:2016, the conveyor belts are classified in classes A, B1, B2, C1 and C2 the requirements of electrical safety and protection against flammability applying for each category in part depending on the field of use of the conveyor belt respectively the application in which it's to be used [7].

The electrical safety and flammability protection requirements for conveyor belts for use in underground installations are given in Table 1 [7].

Table 1. Electrical safety and flammability protection requirements [7]

Class	Application	Electrical surface resistance EN ISO 284	Friction on steel drum EN 1554, method B2			Flammability EN ISO 340		Spread of a flame EN 12881-1
			Flame	Incandescence	Maximum temperature of the steel drum °C	Group of six specimens (s)	Maximum for one specimen (s)	
A	General use, danger limited only to access and means of escape	≤ 300 MΩ	No	Accepted	Unlimited	< 45/45	15	The length of the remaining test piece undamaged must not be less than 100 mm along the entire length of the conveyor belt
B1	Identical to class A plus Potentially flammable atmosphere. No secondary devices	≤ 300 MΩ	No	No	450	< 45/45	15	The length of the remaining test piece undamaged must not be less than 100 mm along the entire length of the conveyor belt
B2	Identical to class A plus Potentially flammable atmosphere. With secondary devices	≤ 300 MΩ	No	Accepted	Unlimited	< 45/45	15	The length of the remaining test piece undamaged must not be less than 100 mm along the entire length of the conveyor belt
C1	Identical to class B1 plus dust or transported material, fuels	≤ 300 MΩ	No	No	325	< 18/30	10/15	Part of the test specimen must remain undamaged along the entire width of the conveyor belt/ The length of the test specimen which remains undamaged must not be less than 600 mm over the entire width of the conveyor belt or the maximum increase in average temperature must not exceed 140 ºC, calculated conveyor belt length consumed depending on the mass must not exceed 1250 mm and the length of the test specimen left undamaged must not be less than 50 mm across the width of the conveyor belt
C2	Identical to class B1 plus dust or transported material, fuels and additional sources of ignition.With secondary devices	≤ 300 MΩ	No	Accepted	Unlimited	< 45/45	15	-

4 Hazard identification and risk assessment in order to select the types of conveyor belts appropriate to the specific application in the field

The task of selecting the types of conveyor belts appropriate to the specific application in the field falls to the user and this involves identifying hazards and assessing risks.

The following hazards have been identified as directly related to the use of underground conveyor belts, to which are added the basic hazards associated with access and limited means of evacuation due to limited working areas [8]:

- accumulation and discharge of electrostatic energy, which can ignite the explosive atmosphere or cause electric shocks to personnel;

- local heating by friction due to either a driven rotational movement and a blocked belt, or a blocked drive and a moving conveyor belt, which may ignite the belt, explosive atmosphere or combustible dust;
- ignition of a conveyor belt from a small heat source such as an open flame, blocked rollers or friction between the belt and the supports or the structure of the supports;
- propagation of a fire along a conveyor belt that ignited.

The risk or the probable frequency occurrence of their dangers and the degree of deterioration they may cause vary depending on the specific circumstances of the application or place of use which are multiple and varied. Consequently, the level of security to be ensured varies from one application to another, depending on the relevant risks [8].

The hazards listed above are not considered to be the only properties that may affect safety and security in operation. It is important to take into account other issues, such as environmental and health requirements. Depending on the end-use requirements, these other factors may affect the category of the selected conveyor belt, conditions in which additional protection measures may be required.

The risk appreciation must identify the hazards to be studied as well as the probability of the operations and the severity of their consequences. Relevant to carry out this assessment are the laboratory tests that must ensure the determination of the properties of the conveyor belts in relation to the ignition sources that they can generate during operation.

The risk assessment must also take into account all possible additional hazards and examine whether secondary safety measures need to be taken in connection with, or in the exchange of test requirements so as to achieve an appropriate level of safety during operation. For example, the level of fire resistance necessary of a conveyor belt may depend on whether or not secondary safety devices are used at the intended place of use.

To the extent that it is not absolutely possible to determine the level of fire resistance necessary to ensure safety conditions, in the risks assessment, it is important to apply the results of the experience accumulated. The experience accumulated provides an important volume of data on the use of conveyor belts in underground installations in complete safety, useful information for developing recommendations on requirements that may be necessary to ensure safe operation.

In the case of conveyor belts used in underground installations, in order to determine which class of conveyor belt is appropriate for the field application, the user must make an appreciation of the danger of ignition. An example in this context is the assessment of the flammability hazard for a belt conveyor intended for use in a potentially explosive atmosphere.

The appreciation of the ignition hazard involves the identification of all possible sources of flammability by classifying them according to their occurrence (normal operation, foreseeable failures), identifying/establishing measures to be applied to avoid activation of ignition sources (transformation of potential ignition sources into active ignition sources), respectively protection against flammability.

Table 2. Example of appreciation the danger of flammability [8]

Possible sources of flammability		**Examples of measures to be applied to avoid activating the sources**	**Protection used against flammability**
Normal operation	**Mistakes that cannot be ignored**		
Static electricity discharge		Use of a conveyor belt with sufficient conductivity to avoid energy overload (surface resistance less than 300 MΩ, test according to EN ISO 284)	EN 13463-1 (instructions for replacing the conveyor belt)
	The conveyor belt is blocked / damage, the drive drums continuing to rotate	Conveyor belt subjected to a friction test according to EN 1554 Without secondary safety devices in the installation, that is why a conveyor belt was chosen according to the requirements of class B1 of EN 14973	EN 13463-5 (constructive security „c")

The results obtained on the basis of the identification and assessment of risks allow the subsequent selection of those classes of conveyor belts, which, being suitable for field application, contribute to ensuring an appropriate level of security.

The classes, categories of conveyor belts, which can be selected for use, are given in the standards SR EN 14973:2016 and SR EN 12882:2016. A conveyor belt is considered to be class A, that belt where the only dangers are access and limited means of evacuation. The conveyor belt category B is that belt which is intended for use where access and means of evacuation are limited, in a potentially explosive atmosphere, and where secondary safety devices do not exist (class Bl) or exist (class B2).

Instead, the conveyor belt intended for use where access and means of evacuation are restricted, in a potentially explosive atmosphere, or when other flammable materials or dusts are transported or is a potential source (flammable charge) and where secondary safety devices do not exist (class Cl) or exists (class C2) is considered to be part of class C.

Category 1, according to the standard SR EN 12882:2016, includes conveyor belts that meet the requirements regarding electrical conductivity. Category 2A and 2B include conveyor belts which meet both the requirements for electrical conductivity and those relating to flame resistance, and category 3A and 3B those which also meet the requirements for drum friction [8].

Category 4A identify conveyor belts that meet the requirements for electrical conductivity, flame resistance and flammability resistance in the simulation of fire, while those in categories 4B, 5A, 5B and 5C meet both the requirements for electrical conductivity and those for flammability (flame resistance, friction resistance on the drum, resistance to fire propagation).

In the context of the theoretical aspects mentioned above, the laboratory tests are of particular importance, as the results obtained after performing them allow the determination of the class, category of conveyor belt, thus facilitating user selection of the type of conveyor belt suitable for field application.

By selecting some classes, categories of conveyor belts appropriate to the field application, the required level of safety and health is ensured, which makes the risk of hazards related to the functionality and properties of conveyor belts to be minimal. However, the important role that safety devices have in ensuring the level of safety and health must not be neglected.

It is known that conveyor belts are an essential component of transport systems, commonly known as conveyors. The transport systems currently in use are equipped with safety devices, their role being to prevent dangerous situations.

Examples of safety devices are conveyor belt alignment devices, conveyor belt tensioners, conveyor blockage/overload detection devices, funnels, gutters, thermal detectors, shaft rotation detectors, etc.

5 Conclusions

The paper deals aspects related to the importance and also the need to test by standardized test methods the properties of the flammability of conveyor belts for use in potentially explosive environments, presenting the methods and test stands that allow testing these properties.

The paper, through its content, provides useful information both to the manufacturers of conveyor belts and especially to their users who have to select in order to use those types of conveyor belts that are suitable for field application.

The paper contributes to informing all stakeholders (manufacturers, users, market surveillance bodies) about the importance of selecting those types/categories of conveyor belts suitable for the field application, based on the results obtained from testing and

assessment in relation to safety requirements and to prevent the risk of initiating potentially explosive atmospheres, the ultimate purpose being to ensure the highest possible level of security in these potentially explosive atmospheres.

The operation of conveyor belts can be associated with the occurrence of hazardous situations which are influenced both by the properties of the conveyor belts on flammability, friction resistance on the drum, charging with electrostatic charges and environmental and health conditions.

In general, hazardous situations arising from the operation of conveyor belts are sources of ignition for explosive atmospheres generated by gases, vapors, flammable mists and/or combustible dusts mixed with air.

Conveyor belts intended for use in potentially explosive atmospheres must comply with the essential safety and health requirements relating to explosion prevention and protection.

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