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CONSIDERATIONS FOR THE EXPLOSION RISK ASSESSMENT OF TECHNICAL INSTALLATIONS OPERATING IN ATMOSPHERES WITH COMBUSTIBLE DUST

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Abstract: The presence of combustible dust suspended in the air or deposited in layers on certain surfaces can lead to fires or even explosions with devastating effects. Particular attention should be paid to the identification and implementation of measures and means necessary for the protection and prevention of dust explosions, all the more so as the damage caused by a dust explosion is generally greater than that caused by explosions. flammable gases and vapors. A dust explosion may occur if, in addition to a potentially explosive dust / air atmosphere, a source of ignition is present. The physio-chemical properties of the present powders must also be taken into account, as well as the parameters of the necessary technical equipment and the operations that make up the applied technological processes.

This paper outlines the steps to be taken to carry out an explosion risk assessment in facilities where combustible dusts are processed, in order to establish prevention and protection measures, in order to ensure a tolerable level of risk.

Keywords: dust-air mixture, explosive atmospheres, explosion risk.

1. INTRODUCTION

In the presence of oxygen, combustible dust that is suspended or deposited on various surfaces can cause fires or even explosions. In most cases, explosions of combustible dust can lead to considerable material damage and sometimes even loss of life.

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The danger of explosion in combustible dust processing plants must be treated as a major hazard, as the explosions can affect both the bodily integrity of the personnel involved in the production process and the environment as a whole.

Therefore, it is necessary to adopt and implement precautionary measures to prevent and ensure explosion protection. These measures must be developed following an explosion risk assessment existing in the analysed installation.

The assessment of the risk of explosion in an installation in which combustible dusts are processed will take into account the nature of the hazardous materials and substances present in the form of dust used in technological processes, protective systems and technical equipment that make up the analyzed plant.

An explosive atmosphere of combustible dust is defined as a mixture of combustible dust air, dust or flakes, a mixture in which, after ignition, combustion is transmitted to the entire unburned mixture. [1]

An explosion occurs when combustible dust is present in suspension when mixed with air in the explosive range of those dusts, ie between their lower explosive limit (LFL) and upper explosive limit (UFL), at the same time as a source of ignition. whose initiation energy is high enough to ignite the air / dust mixture formed. The explosion of combustible dust occurs if there is a simultaneous interaction of the combustible substance with the oxidant and the ignition source, also taking into account the aspects related to the closure of the mixture. In this situation the pentagon of the explosion, shown in Figure 1 can be defined. [2], [3], [4].

Fig.1. Pentagon of explosion

The factors on which the violence and dynamics of an explosion depend are presented below:

✓ The chemical composition of the combustible dust - a combustible dust is characterized by the specific constant of the respective dust, constant which also bears the name of explosion index. This explosion index is a measure of the explosive value of combustible dust. Depending on the explosion index, the fuel dust can be divided into four explosion classes, as can be seen in table no. 1.

Table 1. ***Classification of combustible dusts according to k_{st}.***

Dust Explosion Class	Kst [bar×m/s]	Characteristic
St 0	0	No explosion
St 1	>0 ÷200	Weak explosion

St 2	>200 ÷ 300	Strong explosion
St 3	>300	Very strong explosion

✓ The concentration of combustible dust mixed with air - is the factor depending on which may or may not form a potentially explosive atmosphere. If the concentration value is too low or too high, no explosion occurs. In this case, only a slow combustion reaction may occur. Thus, an explosion can only occur if the concentration of combustible dust is within the explosive range of that combustible dust. In general, the literature states that the lower explosive limit is between 20 and 60 g/m^3, while the upper explosive limit can be between 2 and 6 kg/m^3.

✓ The particle size of the dust particles has a decisive role in determining the severity of an explosion. In this sense, the finer the dust particles look, the lighter they are and the lower they tend to be suspended in the air for a longer period of time.

✓ Homogeneity of dust clouds formed and the way dust particles are present;

✓ Aspects related to how cleanliness is ensured in areas affected by the presence of combustible dust. If there is no cleaning plan according to which a systematic cleaning is ensured, there is a possibility that the suspended dust particles will be deposited on different surfaces, which leads in time to the formation of layers or dust deposits of different thicknesses. In the event of an explosion, these layers or deposits of dust may be swirled, thus providing the fuel needed for other secondary explosions.

2. ANALYSIS OF POSSIBILITIES TO ELIMINATE OR MINIMIZE THE RISK OF EXPLOSION

2.1 Principles of explosion prevention and explosion protection [5]

The basic principles of explosion prevention and protection start from the need for an explosive atmosphere to coincide with the existence of an effective source of initiation, in conjunction with the analysis of the expected effects of an explosion. These can be addressed in the following order:

a) the concept of explosion prevention - can be materialized by:
- avoiding the presence of explosive atmospheres of combustible dust. This objective can be achieved by changing the fuel dust concentration to a value outside the explosive range, or by changing the oxygen concentration to a value below the oxygen limit (LOC).
- avoiding efficient sources of ignition.

b) explosion protection - can be achieved by:
- adoption and implementation of protection measures in order to reduce the effects of the explosion. Among these protection measures we can mention: the design and construction of equipment in explosion-proof construction, the release of explosion pressure, the suppression of the explosion, the prevention

of the spread and explosion of the flame. In this case, an explosion is acceptable.

In some cases, the risk of explosion may be reduced or eliminated by implementing only one of the above principles. There are also situations where a combination of these principles needs to be applied to minimize or eliminate the risk of explosion. It should also be noted that the first option is to avoid a potentially explosive atmosphere generated by the air-dust mixture.

In conclusion, the requirement to prevent explosions can be expressed in the following form: the probability that a source of ignition will occur simultaneously with an explosive atmosphere is minimal. Based on this requirement, it is necessary to establish specific requirements that apply to technical equipment and protective systems designed to operate in combustible dust atmospheres.

In order to be able to develop a concept of explosion safety, in each case, it is necessary to select appropriate precautions by following the steps below:

A. Ex-classification of hazardous areas with combustible dusts

Ex classification of hazardous areas is a way of analysing and classifying jobs in industrial facilities where combustible dusts are circulated, in relation to the likelihood of explosive dust / air mixture formation and deposition of combustible dust in the layer. This analysis is especially necessary for the correct choice of technical equipment that is intended for safe use in combustible dust environments, taking into account its characteristics.

It is necessary to specify exactly the nature of the dust and the technical facilities in which it is processed, in order to be able to classify the hazardous areas where explosive air / dust mixtures are present. The following steps will also be taken:

• Identification of the physio-chemical characteristics of combustible dust: size and humidity of dust particles, minimum ignition temperature in the cloud and layer, electrical resistivity, and the corresponding dust subgroup (IIIA, IIIB or IIIC);

• Highlight those spaces and workplaces where combustible dust may be present. The possibilities of forming dust layers must also be known;

• Carrying out an analysis of the probability of explosive dust / air mixtures occurring in different parts of the technical installation in which the combustible dust is processed.

According to SR EN 60079-10-2:2015 [6], Ex classified areas for explosive dust atmospheres are divided into zones, which are identified and classified according to the frequency and duration of the explosive dust atmosphere, as follows:

- **Zone 20**: A place where an explosive atmosphere of dust in the form of a cloud of dust in the air is present continuously or for long periods of time or frequently.

- **Zone 21:** A place where an explosive atmosphere of dust in the form of a cloud of dust in the air is likely to occasionally occur during normal operation.

- **Zone 22:** A place where an explosive atmosphere of dust in the form of a cloud of dust in the air is not likely to occur during normal operation, but which, if it occurs, will persist only for a short period of time.

B. Establish the zoning plan and the appropriate location of the warning signs

In accordance with the requirements and provisions of European Directive 1999/92/EC [7], it is necessary for the employer to classify into zones all workplaces where dust and / or combustible dusts are present and where, by default, atmospheres may occur. potentially explosive. At the same time, the warning sign "Ex", which must comply with the requirements set out in European Directive 1999/92 / EC on shape, color and size, shall be displayed in workplaces where potentially explosive atmospheres may form.

C. Prevention of ignition sources

The sources of ignition of combustible dusts may be of an electrical and / or mechanical nature. Among these sources of ignition we mention the following:

- hot surfaces;
- electric springs that may be present in switches, contacts, brushes, etc.
- electrostatic discharges;
- thermal sparks;
- mechanical or frictional sparks;

In order to avoid the occurrence of efficient ignition sources, in areas with combustible dust, where potentially explosive atmospheres may form, one of the explosion protection measures that can be adopted is the selection of electrical and non-electrical equipment with Ex type of protection appropriate to those areas.

Tables 2 and 3 show the types of Ex protection that technical equipment intended for use in hazardous areas with combustible dust may present, as well as their choice according to the Ex classified areas in which they may be located.

Table 2. ***Types of explosion protection for electrical equipment in dusty areas***

Types of protection / reference standard	**Category 1 EPL a** Very high level of protection	**Category 2 EPL b** High level of protection	**Category 3 EPL c** Normal level of protection
	USE Zone 20 Zone 21 Zone 22	USE Zone 21 Zone 22	USE Zone 22
Optical radiation interlocked with optical breakage SR EN IEC 60079-28	-	Ex op sh	-
Intrinsic safety Ex i SR EN IEC 60079-11 SR EN IEC 60079-25	Ex ia	Ex ib	Ex ic

systems			
Inherently safe optical radiation SR EN IEC 60079-28	Ex op is	-	-
Encapsulation Ex m SR EN IEC 60079-18	Ex ma	Ex mb	Ex mc Ex n*
Pressurised enclosure Ex p SR EN IEC 60079-2	-	Ex pxb, Ex pyb	Ex pzc
Protection using enclosure Ex t SR EN IEC 60079-31	Ex ta	Ex tb	Ex tc
Protected optical radiation SR EN IEC 60079-28	-	Ex op pr	-

Table 3. ***Types of explosion protection for nonelectrical equipment in dusty areas***

Types of protection / reference standard	**Category 1** **EPL a** Very high level of protection	**Category 2** **EPL b** High level of protection	**Category 3** **EPL c** Normal level of protection
	USE Zone 20 Zone 21 Zone 22	USE Zone 21 Zone 22	USE Zone 22
Constructional safety SR EN IEC 80079-37	Ex h	Ex h	Ex h
Control of ignition source SR EN IEC 80079-37	Ex h	Ex h	Ex h
Liquid immersion SR EN IEC 80079-37	Ex h	Ex h	Ex h
Pressurised enclosure Ex p SR EN IEC 60079-2	-	Ex pxb, Ex pyb	Ex pzc
Protection by enclosures Ex t SR EN IEC 60079-31	Ex ta	Ex tb	Ex tc

D. Choice of technical equipment

After the classification of hazardous areas Ex, identified the combustible dusts that can generate potentially explosive atmosphere, their ignition temperatures and the environmental characteristics around the technological installation, the technical equipment to be used in these hazardous areas can be selected.

The selection of technical equipment must take into account the category of equipment. It must correspond to the type of classified area, depending on the level of protection required in accordance with the criteria set out in Table 4.

Table 4. ***Selection of technical equipment intended for areas with combustible dust***

ZONE	Presence of the explosive atmosphere (explosion hazard)	Avoidance of effective ignition sources (ignition hazard)	Required level of protection	Group II CATEGORY	EPL
22	Infrequently and for a short period only	During normal operation	NORMAL	3D	Dc
21	Likely to occur	Also during foreseeable malfunctions (single fault)	HIGH	2D	Db
20	Continuously, for long periods or frequently	Also during rare malfunctions (two independent faults)	VERY HIGH	1D	Da
USERS		**MANUFACTURERS**			
Directive 1999/92/EC (HG 1058/2006)		**Directive 2014/34/EU (HG 245/2016)**			

3. IGNITION RISK ASSESSMENT ISSUES FOR BUCKET ELEVATORS

The likelihood of a fire or explosion depends on the likelihood of a potentially explosive atmosphere, the existence of sources of ignition and the actual ignition. In the case of a bucket elevator, the consequences of a fire or explosion are determined by the location of the bucket elevator and the proper presence of the protection systems.

Thus, if the ignition of combustible dust inside a bucket elevator occurs, we can have as a result of this ignition the appearance of a smoldering fire, a fire that manifests itself with flame, an explosion or even a propagation explosion. If there is an explosion of dust, a fire may spread inside or outside the bucket elevator.

Another particularly important aspect to consider when evaluating the risk of explosion in bucket lifts is the nature and appearance of the bulk product. In this case, a decisive role is played by the fine fraction of the bulk material, with particle sizes smaller than 500 μm and how easily a cloud of dust forms.

Even if the concentration of combustible dust mixed with air is low, over time, the existing dust may adhere to the surface of the elevator housing, resulting in the formation of dust layers up to a few millimeters thick. Although these dust layers are not in themselves explosive mixtures, however, in the event of damage to the bucket elevator, the housing may shake, leading to turbulence of the adherent dust and the formation of clouds of explosive dust.

In most cases, in the case of a bucket elevator, it is difficult to assess the risk of explosion. Normally, the person using the bucket elevator will choose it according to his category and then perform a risk analysis and assessment according to local circumstances.

In principle, the analysis of the danger of fire and explosion in the case of a bucket elevator can be done by going through the logic diagram shown in Figure 2.

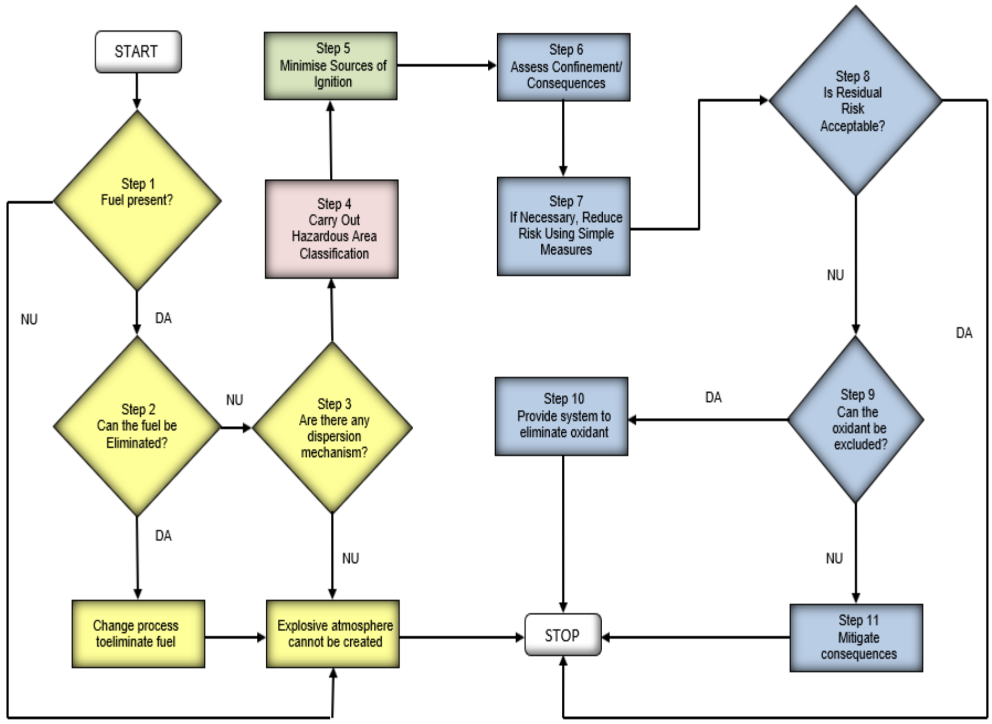

Fig. 2. The explosion risk logic diagram

If we analyse the above logic diagram, if there is fuel dust, it is observed that, after the classification of hazardous areas, it is necessary in the first phase to identify the sources of ignition. It is also necessary to check whether the protection measures adopted and implemented can prevent the occurrence of effective ignition sources in the following cases.:

- during normal operation, if the potential ignition source is in zone 22;
- and during foreseeable failures (for a single failure), if the ignition source is in Zone 21;
- and during rare failures (two independent failures) if the ignition source is in Zone 20.

From the point of view of the existence of potential sources of ignition, in the case of bucket elevators, the following sources of initiation can be found:

Equipment ignition sources - are shown in Table 5.

Table 5. ***Equipment ignition sources***

Potential ignition sources	Possible causes
Hot surfaces	• Bucket lifting belt friction with elevator housing wall due to misalignment • Friction between the lift belt and the drive wheel (drum) due to slipping • Friction of loose parts in the elevator with buckets (loose bucket, lost pulley parts, etc.) with moving parts • Damage to bearings and gears
Mechanical sparks	• Mechanical sparks due to cups colliding with the housing wall (due to insufficient belt tension, defective belt, loose cups) or with the discharge chute • Non-alignment of the drive wheel
Electrical equipment	• Electrical equipment and motors • Improper grounding and / or equipotential bonding
Electrostatics	• Electrostatic charging due to the separation processes between the belts and the drive pulleys • Electrostatic charging of cups due to electrostatic induction •Electrostatic charging of any other installed conductive components that is not grounded

Ignition sources introduced or acting from the outside.

A summary of the potential sources of ignition introduced or acting from the outside is given in Table 6.

Table 6. ***Ignition sources introduced or acting from the outside***

Potential ignition sources	Possible causes
Hot surfaces	• Foreign material introduction • Incandescent particles introduction • Welding, grinding, cutting operations • Damage to the housing due to external mechanical action
Hot flames and gases, including hot particles	• Incandescent particles introduction • Fire or explosion propagation from connected or external installations
Mechanical sparks	• Foreign material introduction • Damage to the housing due to external mechanical action
Lightning	• Inadequate lightning protection

Ignition sources from the product itself.

There are also possible sources of ignition arising from the product itself. Depending on the characteristics of the bulk dust, it must be checked whether self-ignition or exothermic decomposition can occur.

In the case of bucket elevators, large accumulations of dust are expected to form in the feed base and in the horizontal feed and outlet sections. It should be noted that with increasing volume and thickness of the dust layer, the temperature of self-ignition or degradation will decrease.

4. CONCLUSIONS

The assessment of the danger of ignition and explosion, given the use of technical equipment and protection systems in hazardous areas with combustible dusts, is of particular importance for ensuring the health and safety of workers involved in the production process. In accordance with the provisions and requirements of the legislation in force, both equipment manufacturers and their users are responsible for assessing the risk of explosion and for adopting and implementing the necessary protection measures to ensure an acceptable level of safety.

To this end, a risk analysis must be carried out on all technical equipment that makes up an installation operating in hazardous areas with combustible dust, which identifies all potential sources of ignition and all protective measures to be taken and implemented in order to prevent potential sources of ignition from becoming effective.

The technical equipment used will be selected on the basis of the classification of hazardous areas in the three zones 20, 21 and 22, the identification of existing combustible dusts, ignition temperatures, the environmental characteristics of the site and taking into account the category of equipment to be appropriate. with the type of classified area.

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