Development of methods for assessing the safety of dust removal facilities in environments with a danger of explosive atmosphere

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Abstract. Due to the tightening of air pollution laws and employee safety regulations, manufacturers are being forced to pay more and more attention to removing dust particles from the air released by their installations. This requires them to install large complex dust collection systems in all their facilities. Dust collection systems include collection points where air and entrained dust are drawn into a system of pipes that carry dust and air, fans that feed the movement of air, and dust collectors that separate dust from air. Dust collectors are mostly dry type. Dry-type dust collectors are divided into cyclones and bag-type dust collectors. As dust can create an explosive atmosphere, it is necessary to assess the risk of explosions and to establish appropriate measures to prevent the explosion or, as the case may be, to limit the effects of explosions. The paper presents aspects related to the evaluation of the risk of explosions at dust removal installations with emphasis on the risk of initiating the explosive dust / air atmosphere through electrostatic discharges.

1 Introduction

Due to the tightening of air pollution laws and employee safety regulations, manufacturers are being forced to pay more and more attention to removing dust particles from the air discharged from their installations. This requires them to install large complex dust collection systems in all their facilities. However, these dusting systems must be evaluated for the risk of explosion as most dusts can generate an explosive atmosphere in order to establish explosion prevention or protection measures.

To prevent an explosion, the explosive atmosphere and efficient ignition sources must be prevented. If sufficient measures cannot be taken to prevent the explosion, measures must be taken to limit the effects of that explosion by means of protective systems.

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2 Severity of explosion and sensitivity to ignition of dust

Each installation must be analyzed for fire and explosion hazard by following the logic diagram shown in Figure 1 [1].

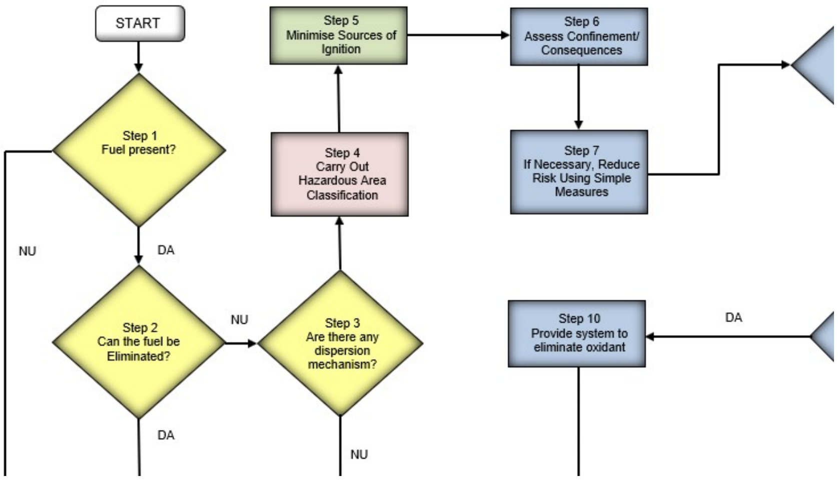

Fig. 1. Logical diagram for fire and explosion risk analysis.

When performing this analysis, it is important to characterize the hazard risk of the material in question by determining the severity of the explosion and the sensitivity to ignition, defined as the combustion characteristics.

The most important combustion characteristics for combustible dusts are, according to the series of standards SR EN 14034-1,2,3: Determination of explosion characteristics of powder clouds, [2]:

- Maximum explosion pressure Pex - the highest overpressure that occurs during an explosion of a powder mixture in a closed vessel;
- Maximum pressure rise rate (dP / dt) max - the maximum value of the pressure increase per unit time during explosions, for all explosive atmospheres in the explosive range of combustible substances in a closed vessel under the specified test conditions and atmospheric conditions standard;
- Severity explosion factor - K_{max}, K_{st} volume independent characteristic that is calculated using the cubic equation:

$$(\mathrm{dP/dt})_{\mathrm{max}} \times \sqrt[3]{\mathrm{V}} = const. = K_{st} = K_{max} \quad (1)$$

- where V represents the volume of the test vessel, in our case the volume of the sphere is 20 liters;

- Minimum explosion concentration or lower explosion limit (CmEx, LIE or LEL) - lowest concentration of a combustible dust in mixture with air at which an explosion occurs.

The severity of the explosion is measured by how quickly the pressure in a standard enclosure increases when the dust in question is ignited (Figure 2).

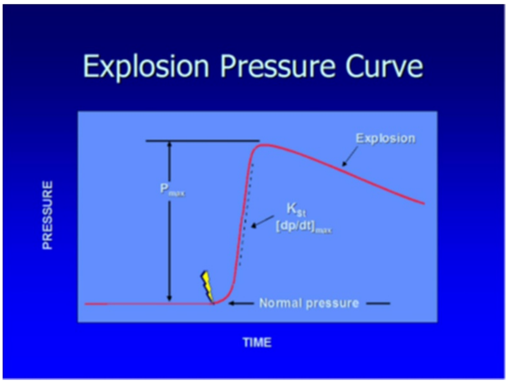

Fig. 2. Pressure explosion specific curve.

The violence of a dust explosion is influenced by several factors. The first and most obvious is the dust material itself Kst (dust explosion constant) which is a measure of the explosiveness of combustible dust. Kst is measured in bar.m / sec.

Table 1 shows the Kst values according to which combustible dusts are divided into explosion classes on the one hand and classified into explosive or non-explosive on the other.

Table 1. Classification of combustible dusts according to Kst.

Dust explosion index	K_{St} [m·bar/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

In order to form a potentially explosive atmosphere, flammable substances must be present in a certain concentration, ie in the range determined by UEL (upper limit of explosiveness) and LEL (lower limit of explosiveness). If the concentration is too low or too high there is no explosion but there is only a slow burning reaction. A concentration of 20 g / m3 is below the minimum explosive limit for most types of dust. Obviously, dust concentrations above the minimum explosive limit do not usually occur in work areas. However, these concentrations frequently exist inside the equipment (silos, filters, bucket elevators, conveyor housings, etc.).

Other factors that play an important role in the efficiency of the explosion propagation process are: particle shape, particle size distribution, combustion chemistry, the presence of contaminants (such as vapors, gases, or inert particles), atmospheric turbulence, and particulate moisture content.

The size of the dust particles plays an important role in determining the severity of an explosion. A solid fuel burns only on its surface, where it is exposed to air. A cloud of very fine dust particles has a much larger surface area than a cloud of coarser particles. In addition, fine particles weigh less and tend to remain suspended in the air longer. To cause an explosion, the combustible mixture of air and dust must be contained in a certain type of vessel.

Changing the particle size or moisture content can radically change the severity of the explosion.

Another factor that strongly influences the severity of a loss is the dust deposited on the exposed horizontal surfaces. When a dust explosion occurs, the first explosion is usually small. The shock of that initial explosion swirls the existing dust in the air, creating a large cloud of dust that then ignites to cause a much more severe secondary explosion. This explains the emphasis on cleanliness.

3 Dust collection systems

Dust collection systems include collection points where air and entrained dust are drawn into the system, ducts that carry dust and air, fans that supply air movement, and dust collectors that separate dust from air. Dust collectors are mostly dry type. The dry type is further divided into cyclones and bag-type dust collectors.

Below is a typical dust processing plant (Figure 3):

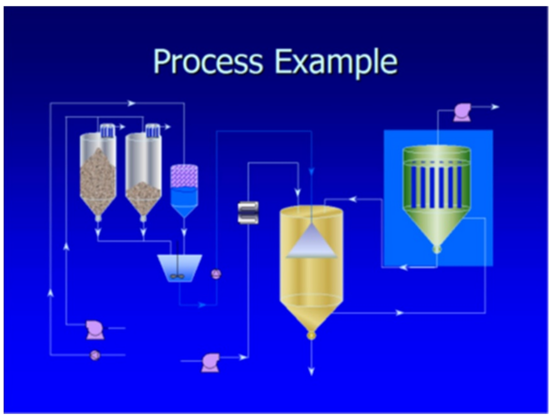

Fig. 3. Typical example of a powder processing plant.

Pipeline

The pipes are used to transport the airborne dust from the collection points to the dust collectors themselves. Pipeline hazards include obstruction of ceiling sprinklers, fuel construction, and combustibility of pipe contents.

Fans

The fans supply the air movement needed to transport the dust to the collectors. The danger associated with the fans is limited to providing a source of ignition. Ignition can be from overheated bearings, electric short circuit or sparks from a fan due to misalignment or breakage (if a wrong metal was used in its construction).

Dust collectors

Cyclone manifolds (cyclone filters) are conical units that operate by forcing air-entrained dust to flow in a downward spiral. This increases the speed of the current and, therefore, the centrifugal forces on the dust particles, causing them to be thrown outwards against the part of the cyclone. Dust particles then fall to the bottom of the cyclone and into a recovery basket or bunker for disposal or recycling. Clean air comes out at the top of the cyclone. Cyclones vary in diameter, the smaller the diameter, the greater the efficiency. Cyclone collectors work best on dust particles between 10 and 300 microns in size.

Therefore, they are an economical way to handle coarse dust. Because they do not contain filter media and have very little grip, they are preferable to bag-type collectors in order to prevent losses. To handle fine dust, several small, highly efficient units are needed in series. This increases the power requirements of the driving fans.

Collector bags

Bag collectors (bag filters) are rectangular or cylindrical units that operate by forcing air-driven dust through a fabric filter. The fabric filter is called a bag because it is usually shaped into a long narrow cylinder closed at one end. The dust trapped in the bags is removed by mechanical agitation or high-pressure air pulses. Dust falls on a hopper for disposal or recycling. A variant of the bag filter is the type of tube that uses plastic fibers arranged in tubes similar to the air filters of the automatic engine. They are cleaned by stirrers and are most commonly used by foundries. Bag collectors work best for dust particles between 0.01 and 20 microns. These are therefore the most economical way to treat fine dust. With the exception of fuel construction, the only hazards are those posed by combustible dust, ie fire or explosion. If non-combustible (or at least low-fuel) bags are available that are compatible with most dusts and operating temperatures, they tend to cost more. Even if the bags do not contribute significantly to a fire, they may be severely damaged by a fire, regardless of the speed of the fire suppression system.

4 Ignition sources

The most common sources of ignition associated with fires and explosions in dust collection systems are static electricity and hot surfaces [3].

Hot surfaces

A layer of dust on a hot surface tends to increase the heat, thus increasing the local temperature. Over time, the heat will pyrolyze the dust until its ignition temperature is reduced to the surface temperature and ignition takes place.

Static electricity

Because most combustible dusts are carbonic, they are weak conductors and are therefore capable of holding an electrostatic charge. Because these particles are carried by a moving stream of air, they tend to generate and hold large electrostatic charges. If these charges leak to the ground under certain conditions, an electrostatic spark strong enough to cause ignition may be generated. For this reason, the need to ground and connect all system components is very necessary. This is also one of the reasons why plastic pipes are so unwanted.

History of losses

The literature presents a series of explosions or fires in dust collectors [4]. Although the losses caused by the fires were more than six times greater than the losses caused by the explosions, the average loss caused by the explosions cost three times more than the average loss caused by the fires.

If the proper sprinkler systems were in operation, the cost of fire losses was reduced by more than half. The presence of explosion protection or suppression protective systems has led to a similar reduction in the cost of explosion losses.

5 Evaluation of the risk of explosion on ignition of explosive dust atmospheres by electrostatic discharges

For most processes with particles handling organic or even metal products, the formation of a cloud of flammable dust is difficult to avoid. The contact of the product particles with each other and with the walls of the equipment leads to the accumulation of loads on both the product and the equipment. If the charge build up becomes large enough to cause a discharge to the surrounding atmosphere, the flammable dust cloud may be ignited by the hot plasma in the discharge channel.

An explosion of dust may occur if fine particles of a flammable material are dispersed in the air. Particles larger than 0.5 mm in diameter do not participate in the explosion. The finer the particles, the more sensitive the dust cloud is to the ignition sources and the more violent the ignition. Dust explosions, in atmospheric conditions, normally have the following characteristics:

- explosion range: from 20 g / m^3 to several kg / m^3;
- maximum explosion overpressure: 9 bar for organic materials up to 13 bar for metal powders;
- maximum pressure rise rate in a 1 m^3 vessel: from 100-300 bar / s for organic materials to about 1000 bar / s for metal powder.

As far as humans are concerned, dust explosions are normally even more dangerous than gas explosions, as exposure to heat radiation lasts much longer in the case of premiums. The ignition sensitivity of a dust cloud is characterized, as for any other fuel, by its minimum ignition energy (MIE). It can be seen that, for a certain material, the ignition energy proves to be the lowest for the very fine homogeneously dispersed powder to form an almost quiet cloud.

The most common electrostatic discharges in the industry have an energy that is normally less than 10 mJ. Therefore, materials with a minimum ignition energy value of 10 mJ or less are considered to be the most critical. But this is only valid in the absence of flammable gases or vapors. It must be borne in mind that the presence of flammable gases or vapors leads to a ten-fold reduction in the minimum ignition energy for the resulting mixture, generally referred to as a "hybrid mixture". It may even happen that the value of the minimum ignition energy of the hybrid mixture drops to the level of pure gases or vapors (usually 0.2-0.4 mJ for hydrocarbons).

Different forms of discharges, such as sparks, brushes, and propagation brushes, can lead to ignition hazards depending on the discharge energy and the minimum ignition energy of the dust cloud. The appearance of both spark and brush discharges can be eliminated, ensuring that the surface resistance is below 10^{11} Ω and above 10^{8} Ω. Surface resistance can be reduced and brought to the limits mentioned above, using antistatic additives. But there are two problems associated with this measure: the antistatic effect is often dependent on the relative humidity of the environment and antistatic additives are sometimes absorbed by the product in contact with the treated surface.

In addition to the types of discharge mentioned above, there are two other types of discharge and are characterized by the fact that they can occur only in particulate processes. It's about cone discharge and lightning discharge.

6 Assessment of the risk of ignition of the atmosphere of combustible dust / air in containers due to electrostatic discharges

The ignition risk assessment process must take into account that hazardous electrostatic charges can accumulate on both bulk material and container walls.

The risk of igniting the atmosphere of fuel dust / air in containers due to electrostatic discharges depends on the characteristics of the dust, the materials from which the containers are made as well as their dimensions and process. In essence, the risk assessment should start from the conductivity of the dust. If, for example, we have dust with a resistivity ρ >10 GΩ m, then the evaluation is made according to the diagram in Figure 4 [5].

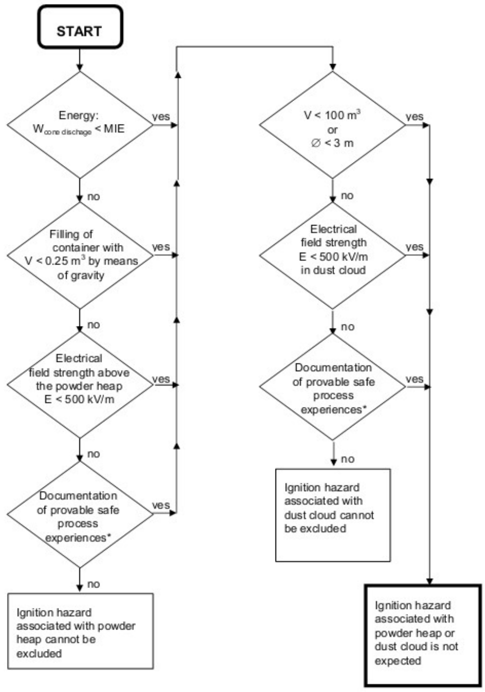

Fig. 4. Evaluation of bulk material having ρ >10 GΩ m.

If the ignition risk is excluded on the basis of the decision stage - Documentation of experience in the safety of the technological process, the risks of explosion should be analyzed in detail and evaluated.

In this context, it should be borne in mind that minor changes in the technological process, products, equipment, packaging, etc., may have a significant effect on the occurrence of flammable discharges, as well as on the occurrence of an explosive atmosphere and its concentration. The relevant justification explaining even the most marginal changes and possible consequences should be explained in an explosion protection document.

If the assessment shows that the risk of explosion cannot be ruled out, measures must be taken to reduce the effects of possible explosions by installing a protective system [6].

7 Conclusions

Ignition risk assessment, when using equipment and protective systems in environments with flammable substances that could cause fires and explosions, is particularly important to ensure the health and safety of workers. According to the legislation in force, the responsibility for risk assessment and the adoption of protective measures necessary to ensure an acceptable level of safety lies with the manufacturers and users of the equipment. [7, 8].

For this reason, dedusting installations must be subjected to a well-documented formal hazard analysis to identify and list all potential sources of ignition and to take the necessary measures to prevent the potential sources of ignition from becoming effective. If the assessment shows that the risk of explosion cannot be prevented, measures must be taken to limit the effects of explosions by means of protective systems.

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