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EXPLOSIONS OF FLAMMABLE INDUSTRIAL DUSTS

Abstract: Dust explosions are a major hazard in many industrial processes. In operations such as crushing, grinding, conveying, classifying and storage, an explosion may occur in the presence of combustible dusts or powders. A lot of accidental dust explosions take place in industrial plants that have powder-processing equipment. This is because more than 70% of powders processed in industry are combustible. It is essential, therefore, to accumulate much knowledge as possible on the explosion hazards of combustible powders. Those cover a wide range of wood dust, food and feeds, metals, plastics, coal, paper and chemicals. (https://www.researchgate.net/publication/265786874_DUST_EXPLOSIONS_-A_MAJOR_INDUSTRIAL_HAZARD)

1. EXPLOSIONS OF FLAMMABLE INDUSTRIAL DUSTS

This lecture will be held in the spirit of these main teaching and learning objectives:

- *Theory of Flammable Industrial Dust Explosions*
- *Flammability, Reactivity and Dust Explosion Hazards*
- *Characteristics, Fire and Explosive Properties of Flammable Dust*
- *Health Properties of Flammable Industry Dust*
- *Process Safety Incidents in Particular Types of Industry*
- *Risk Prevention and Controls*

An explosion of dust is a rapid combustion of fine particles suspended in the air, particularly in an enclosed location.

Flammable dust means a set of pulverized particles of the solid substance which exist in the gassy environment. These dust particles have the dimensions lower than 0,5 mm.

Aerosol is dust sprayed in the air. Aerogel means a dust layer on the surface with its particular thickness. The difference between fires and explosions is for example in the rate released energy.

Fires release energy slowly, explosions release energy rapidly. Fires can result from explosions, explosions can result from fires.

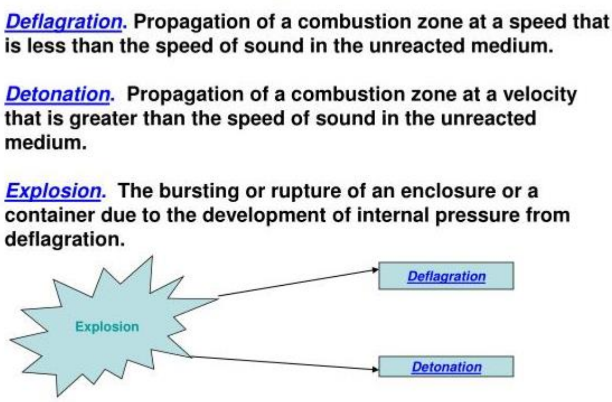

Figure 1 – The main difference between deflagration and detonation (https://www.slideserve.com/perrin/combustible-dust-national-emphasis-program)

In some situations, a subsonic flame may accelerate into a supersonic flame. This deflagration to detonation is difficult to predict but occurs most often when eddy currents *or other turbulence are present in the flames. This can happen if the fire is partially confined or obstructed. Such events have occurred in industrial sites where extremely combustible gasses have escaped, and when ordinary deflagration fires encounter explosive materials. (https://www.slideserve.com/perrin/combustible-dust-national-emphasis-program)*

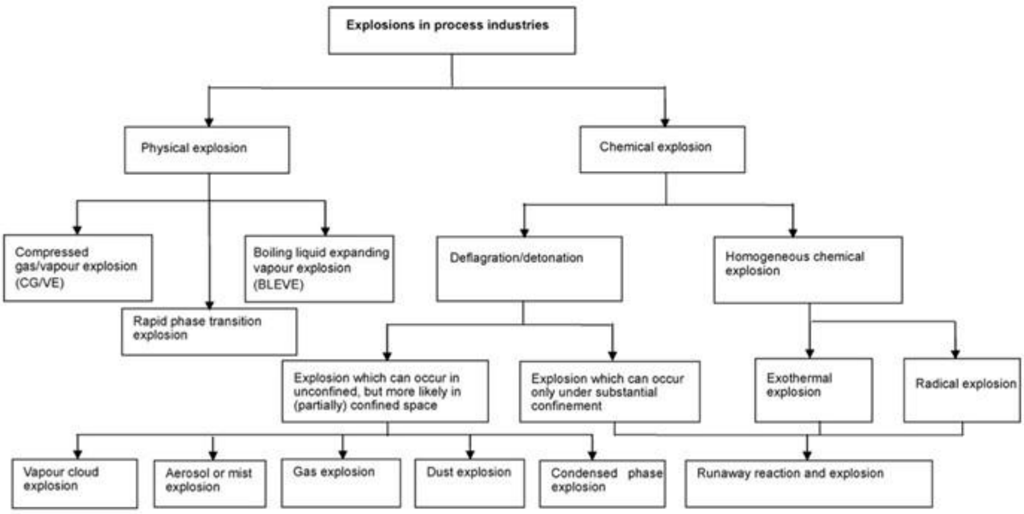

Figure 2 – Types of Explosions in Process Industries (https://slideplayer.com/slide/3828363/)

Surface area increases with increasing subdivision.

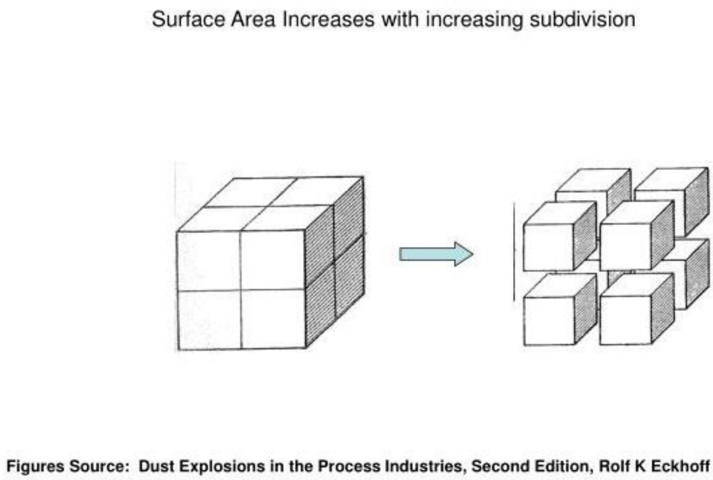

Figure3 – Subdivision of surface area

The difference between dust explosion pentagon and hexagon you can see in the following picture:

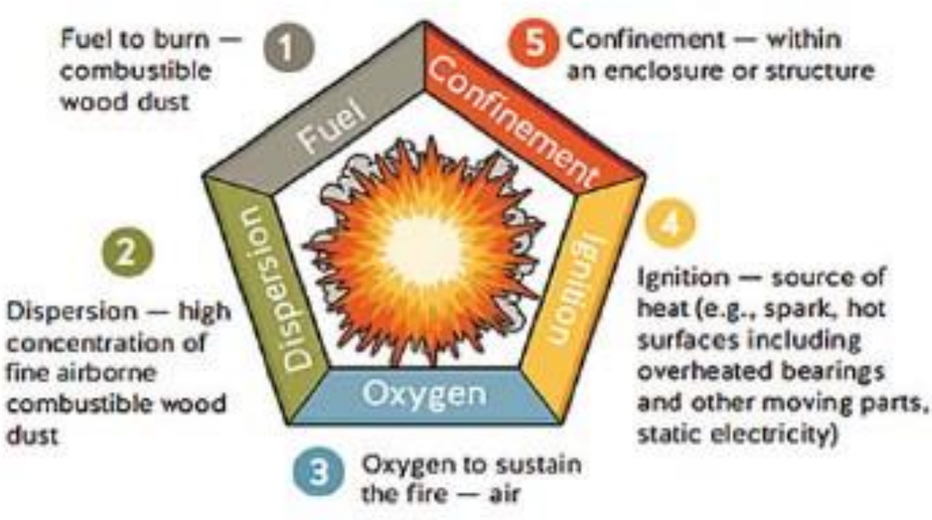

Figure4 – Explosion pentagon (http://www.turkchem.net/combustible-dusts-and-dust-explosions.html)

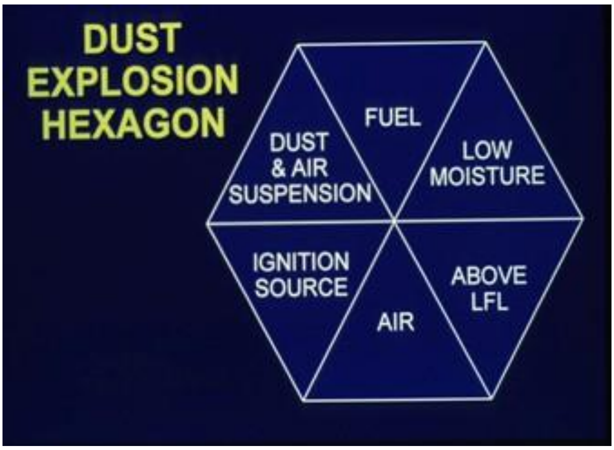

Figure5 – Explosion hexaagon

The maximum explosion pressure p_{max} is significantly influenced by the housing. (https://slideplayer.com/slide/4616500/)

The rapid pressure increase dp/dt reflects the potential severity of an explosion. It is defined as primary point of origin in the deviation point of the pressure/time curve and used as parameter (K_{St} value) for classification into dust explosion classes St 1, St 2 and St 3.

In addition to the maximum pressure, the dust explosion classifications establish the basis for the practical design of protection measures. (https://www.exschutz.net/en/basic-information-on-explosions.html)

Characteristics of flammable dust are:

- *lower explosive limit,*
- *maximum explosion pressure,*
- *maximum rate of pressure increasing,*
- *deflagration index K_{St},*
- *maximum explosive pressure,*
- *minimum ignition energy,*
- *ignition temperature of the settled dust,*
- *ignition temperature of the whirled dust,*
- *limiting oxygen content,*
- *minimum explosible concentration,*
- *etc.*

Typical Dust Parameters	
Cloud ignition energy	5 mJ and higher
Minimum explosive concentration	0.02 oz/ft³ and higher
Maximum pressure developed	30 … 150 psi
Rate of pressure rise	less than 15,000 psi/sec
Ignition temperature—cloud	200 °C and higher
Ignition temperature—layer	150 °C and higher

Figure 6 – Dust parameters typical for many industrial dusts (Ernest C. Magison, Electrical Instruments in Hazardous Locations, 3rd ed. (Pittsburgh: Instrument Society of America, ca. 1978), 317)

Dust explosion has two stages primary and secondary. Primary explosion is an initial part which may dislodge more accumulated dust in the air or a damage in containment system. If this dispersed dust further ignites, one or more secondary explosions can happen.

Secondary explosion can be more destructive than primary due to increased quantity and concentration. (https://technicheengineeringsite.wordpress.com/2016/06/29/combustible-dust-explosion/)

Minimium ignition temperature testing in dust layer means that experimental measurements are carried out on an apparatus for determining the minimum ignition temperature in the settled state according to the procedure in Slovak technical standard STN EN 50281-2-1.

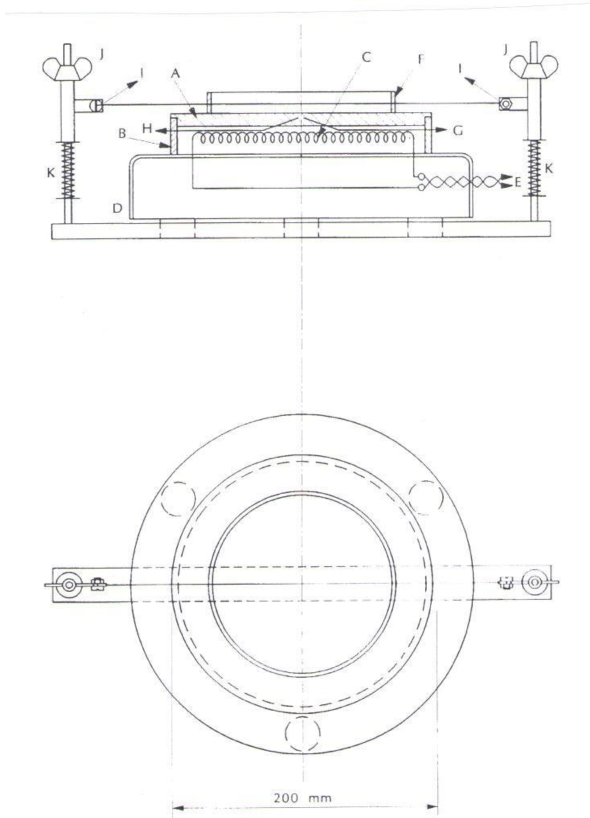

Figure 7 – Scheme of equipment for measuring ignition temperature of settled dust, A - heated board, B - hem (boarder), C - heating, D – base of heating, E - outlet for connection of heating to the power supply and control, F – ring for the dust layer, G - thermocouple in the control board, H - thermocouple in the temperature recorder, I – thermocouple for temperature recording in the dust layer, J - thermocouple height adjustment, K - spring (STN EN 50281-2-1.)

Minimium ignition temperature testing in dust layer provide information on sensitivity to ignition by hot environments, hot surfaces, etc. (https://www.slideserve.com/william-doyle/dust-explosion-hazard-assessment-and-control-an-overview)

Figure 8 – Scheme of equipment for measuring ignition temperature of whirled dust (https://www.sigma-hse.com/process-safety-testing/dust-and-powder/minimum-ignition-temperature-mit)

ATEX directive

ATEX is an abbreviation for "ATmosphere EXplosible". At the same time, ATEX is the abbreviated name of the European Directive 2014/34/EC concerning the placing on the market of explosion-proof electrical and mechanical equipment, components and protective systems. It came into force on 1 July 2003, and all new equipment and protective systems have been subject to it since that date. (https://www.simona.de/en/service/atex/definitions/what-is-atex/) There are two ATEX directives (one for the manufacturer and one for the user of the equipment):

- the ATEX 95 equipment directive 94/9/EC, Equipment and protective systems intended for use in potentially explosive atmospheres (This directive is superseded by the new one, as indicated afterwards. The information in this article is not yet updated and some information refers to the old one.)
- the ATEX 137 workplace directive 99/92/EC, Minimum requirements for improving the safety and health protection of workers potentially at risk from

explosive atmospheres. (https://www.simona.de/en/service/atex/definitions/what-is-atex/)

Directive 2014/34/EC (ATEX 95) defines specifications for the provision and use of electrical and non-electrical equipment in an explosive atmosphere. The essential safety and health protection requirements for equipment are defined in a classification system. The requirements defined by the two Directives for manufacturers and plant operators are shown in the table below. (https://www.simona.de/en/service/atex/definitions/what-is-atex/)

Primary protection – measures to prevent or to minimize the formation of an explosive mixture, it is to eliminate at least one of the factors necessarily present in the explosion of flammable dust.

Secondary protection - measures to prevent ignition of the explosive mixture.

To eliminate an explosive dust-oxygen mixture it is possible to use industrial vacuum cleaners or adding inert substances (e.g. nitrogen, carbon dioxide, water vapor, limestone) to areas with an explosive atmosphere to keep the oxygen concentration below the limit (eg in mills, dryers, etc.).

Secondary protection is the elimination of initiating resources, which may be, for example, hot surfaces, flame, hot gases, mechanical sparks, electrical operating equipment.

Conclusion

Safety with the appearance of flammable metal dust is linked to the observance of principles, including a detailed analysis of the relevant technological process and consideration of the possibility of emergencies.

The practical application of all legislation applicable to the relevant technological operation can greatly prevent the occurrence of extraordinary events associated with the explosion of flammable metal dust, thereby saving the human lives, protecting the health of workers as well as specific technological facilities and operations.