Course Name: Theory of Fire Propagation (Fire Dynamics)

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Week – 11

Lecture – 03

Module 8 – Introduction to dust ignition, dust explosion and forest fires

Dust:

Dust (or powders) are micron-sized (< 500 microns) particles. Many materials, which are virtually non-flammable in bulk form, are highly flammable if dispersed in the air like a cloud of fine particles in a well-mixed manner. In that manufacture, transport, process, and use powders or dust run into dust ignition, accidental dust deflagration, or dust explosion, Industries, which manufacture, transport, process and use powders or dust, run into dust ignition, accidental dust deflagration or dust explosion forming a natural hazard to both personnel and equipment. The fire caused by micron-sized particles results in extensive material damage, injury, and loss of life in coal mines, wood, paper, chemicals, food, grain, and pharmaceutical plants. Many organic dusts, such as wheat flour, rice flour, wood powder, sugar, and so on, are highly flammable when dispersed in the air as a cloud of fine particles.

Dust layer ignition:

Ignition due to heat transfer from hot surfaces to flammable dust deposited over them represents a common industrial hazard, especially in facilities that handle dust typically smaller than 400 microns. Fugitive dust is usually trapped in

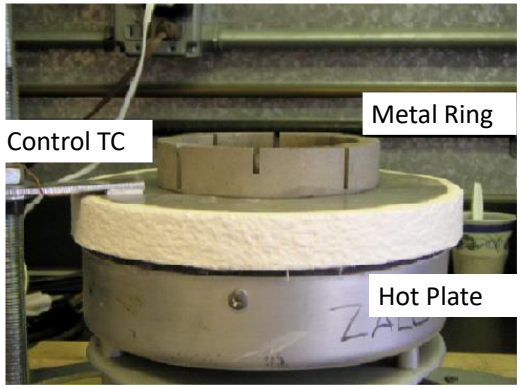
the surfaces of process and handling machinery, switch-boards, electrical conduits, and several other hard-to-reach areas. If these surfaces are above a minimum threshold temperature, the dust deposited over them can undergo spontaneous ignition. This provides an ignition site for nearby combustibles. Spontaneous ignition of dust occurs when enough energy is supplied to it that triggers exothermic chemical reactions leading to a sudden rise in temperature.

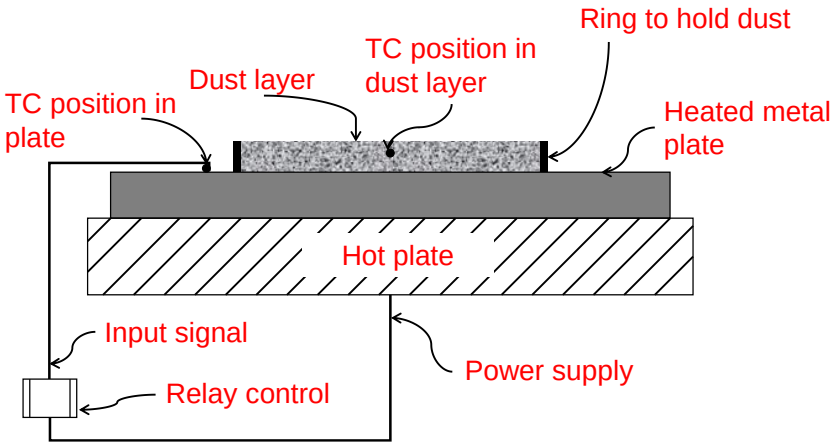
Dust layer ignition on hot surface:

Energy is supplied through radiation, high surrounding temperatures, and high surface temperatures on which the dust deposits. The most common instance of the three is of hot surfaces in industrial equipment and processes that lead to dust ignition. To address this safety issue, tests based on determining a reference minimum temperature necessary for the ignition of a dust layer of a certain thickness are performed. This is done by depositing the dust layer in a ring of standard dimensions kept over a hot plate of known temperature, such that the bottom surface of the dust layer is in contact with the hot plate and the upper surface is exposed to the ambient temperature.

Dust layer ignition test:

Common criteria for ignition in hot surface tests are visible signs of combustion or glowing, or the sample temperature rising to 50 ºC above the hot surface temperature (ASTM E 2021)





Dust layer ignition by ASTM E 2021:

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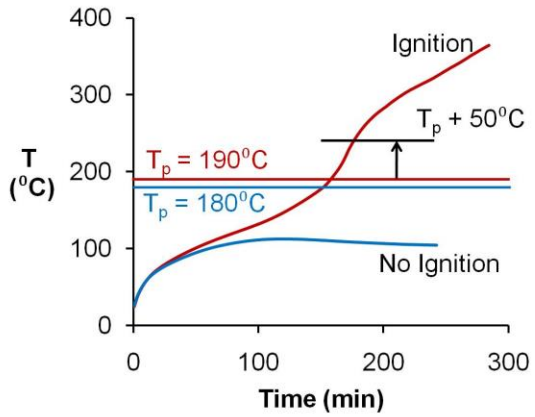


Coal dust after the test where ignition criterion is positive – experiments conducted in WPI, MA, USA.

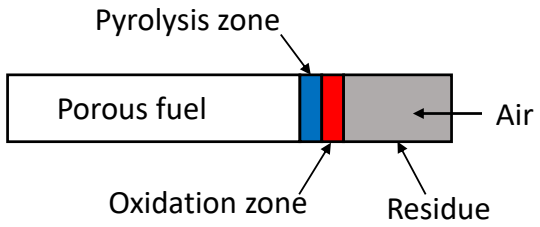
Dust layer combustion – smouldering:

When a layer of dust is in contact with a surface having a critical temperature or a critical heat flux, it reaches the ignition temperature, usually called Self Ignition Temperature. Higher heat flux results in lower time to ignition. Particle size in the layer affects the time to ignition. In charring materials, when oxygen from air contacts the hot char, exothermic surface reaction takes place: $C\ (s) + O_2 \rightarrow CO_2$.

Propagation of this surface reaction through the combustible dust layer or any charring porous material is called **smouldering**. Smouldering is a gradual, low temperature burning process, where a flame (majorly gas-phase reaction) is not associated. Burning of a layer of charcoal particles, cigarette and underground coal are examples of smouldering. Smouldering can occur before or after a flaming combustion (fire).

Smouldering:

Schematic of smouldering process is shown in the figure.



Peak temperature during smouldering is in the range of 450°C to 700°C for typical biomass fuels. For high-ranked coals, it may reach 1000°C. The flame spread rates are also much lower than that in flaming combustion. Heat release rate flux varies from 10 kW/m^2 to 30 kW/m^2. Oxygen supply & heat transfer control the smouldering process.

Smouldering involves preheating, drying, pyrolysis and oxidation. Relative air flow direction controls the smouldering rate.