

Course Name: Theory of Fire Propagation (Fire Dynamics)

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Week – 01

Lecture – 04

Module 1 – Basics of Fires

Liquid fuel properties

Flash point is the temperature at which enough vapor is released from liquid fuel surface to form a mixture with atmospheric air that is ignitable. At flash point, ignition is possible only with the help of a pilot ignition source such as spark or small flame.

Fire point is a temperature more than flash point, where enough vapors are available to sustain a flame over liquid fuel surface. At fire point, vapors generated and air from ambient mix at stoichiometric proportions in the flame zone to sustain a flame without external ignition source.

Boiling point is the saturation temperature, where phase change occurs without a change in the temperature, at a given pressure. When a liquid pool burns by having heat transfer only through its surface exposed to gas-phase, its surface temperature will generally not exceed its boiling point.

Latent heat of vaporization is the heat required per kg of liquid to cause phase change from liquid to vapor (J/kg).

Surface tension is the energy required to increase the surface area of a liquid surface in contact with a gas-phase resisting the intermolecular forces. Surface tension varies due to variation in composition (multiple liquids) and due to temperature and pressure. When a fire of flame is established over the liquid fuel surface, gradients of surface tension is formed. A flow is triggered on the surface from low surface tension to high surface tension point. This is called Marangoni convection. All properties vary as a function of temperature (in some cases with pressure). Since fire is constituted by multi-component gases, proper mixing rules should also be considered to evaluate a property.

Solid fuel properties

Solid fuels are classified as charring and non-charring fuels. Several solids such as wood, coal and biomass are of charring type. These have four constituents – moisture, volatiles, fixed carbon and ash. Moisture is the water vapor trapped in the solid fuel. It will be released when the solid is heated to around 373 K. Volatiles are the gases (non-condensable) trapped within the solid. They are released when the solid is heated to around 500 K to 600 K. Fixed carbon and ash together are called char. When moisture and volatiles leave, char is left behind. Thus, fuels those leave behind the char are called charring fuels. Char has to be heated to around 900 K to 1000 K for the carbon to start reacting. Oxygen and other gases diffuse to the surface of the hot char and surface reactions occur. This is heterogeneous in nature. Ash is an inert mineral content in the solid fuel.

Solids those do not leave behind char are non-charring fuels. Non-charring solid fuels either melt to liquid fuels or monomers, or directly sublime to vapor. Wax and polymers are examples of non-charring fuels. Only impurities, if any, are left behind after combustion.

Pyrolysis is the process in which gaseous components (or volatiles) come out of the solid fuel. This occurs in both charring and non-charring solid fuels. Major heat release reactions occur in gas-phase when these gaseous components involve in gas-phase reactions.

Heat supplied to the solid fuel to extract the gaseous components from it is called heat of pyrolysis (J/kg) or heat of gasification. Latent heat of sublimation (J/kg) is supplied at a given temperature to convert non-charring solid to gas. To melt a solid, latent heat of melting (J/kg) is supplied at its melting point.

Definitions related to fire (Ignition)

Fire is initiated by ignition of a material. Ignition occurs when the surface reached a minimum temperature called ignition temperature. From room temperature, the material has to be heated to its ignition temperature. For this a critical heat flux is required. Time taken for a material to be ignited depends on thermal inertia (ρkc), heat of gasification, ignition temperature and product yield during pyrolysis. These parameters put-together is thermal response parameter.

Ignition is classified as piloted ignition and auto-ignition. Piloted ignition requires a minimum (critical) volume of a flammable reactant mixture and a minimum ignition energy. Auto-ignition occurs when the reactant mixture within flammability limits (proper proportions) is at its auto-ignition temperature. No external source is required for ignition. Phenomenon of auto-ignition can occur in a layer of combustible dust settled over a hot surface. Here, based on the thickness of the dust layer and the temperature of the hot surface, a temperature rise beyond the surface temperature is observed. This is referred to as spontaneous ignition. Auto-ignition of reactant mixtures present in confined space may lead to an explosion. Here, heat release causes an increase in both temperature as well as pressure. This scenario is also observed in compartment (room) fires, where the ventilation is much less. Simultaneous auto-ignition of several commodities in a compartment is referred to as flashover. Auto-ignition also causes a phenomenon called backdraft. This happens when hot fuel gases and vapors are suddenly exposed to a stream of air from atmosphere.