Course Name: Theory of Fire Propagation (Fire Dynamics)

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Week – 04

Lecture – 02

Module 3 – Review of Premixed and Diffusion Flames

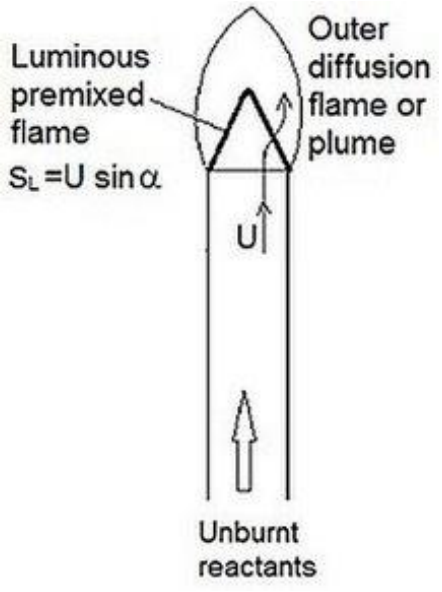
Premixed and diffusion flames:

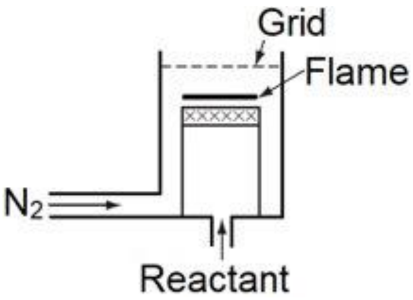
Fires involve reactants (fuel and air) usually not mixed well before combustion. These are called non-premixed or diffusion flames. In fires, the fuel is in a solid or liquid state, and major reactions occur in the gas phase. Therefore, phase change (pyrolysis or evaporation) occurs as the first step. The gaseous fuel must combine with oxygen from the air to form a flammable mixture, which, when ignited, forms the flame zone. This mixing process is generally controlled by diffusion (or aided by convection or turbulence); however, it requires orders of magnitude longer time compared to that of a chemical reaction. Therefore, transport processes such as diffusion of species are the primary controlling processes in such fires.

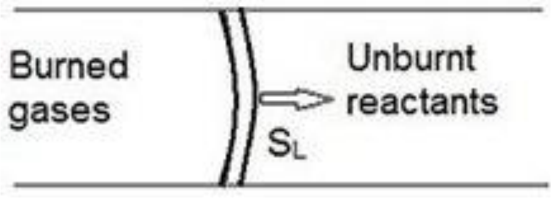
In some cases like compartment fire flash over, deflagrations and fire balls, the fuel vapor and oxygen are mixed before they burn. Such flames are called premixed flames and understanding them forms the basis of explosion safety. The propagation of a flame primarily depends on the amount of reactant mixture available normal to it. The rate of flame propagation is a function of the reactant temperature, equivalence ratio and so on, which control the reaction rate. This translates to “burning velocity”. An estimate of burning velocity is required to calculate the pressure rise as a function of time in a compartment. It is also used to estimate the limits of flammability, flame (reaction zone) thickness, and quenching distance used in the design of explosion prevention systems.

Premixed flames:

When a **fuel** (gas or vapor) is **uniformly** mixed with an **oxidizer** (air) in **flammable proportions**, upon ignition, a flame would initiate and **propagate** through the **reactant mixture**. Steady flame propagation at a subsonic speed is called deflagration or laminar flame propagation. A flame is kept stationary by supplying the reactant mixture at a certain rate, such that the magnitude of its velocity component (U) normal to the flame surface is equal to laminar flame speed (S_L).







Bunsen burner flame:

A *conical* premixed *luminous* flame is formed at the exit of a Bunsen burner. If U is the average velocity of the reactant mixture in the burner tube and α is the **half cone angle**, then the velocity component normal to the flame surface is $U \times \sin\alpha$. This component is equal to the average laminar flame speed, *SL*. Flame speed is also determined by dividing the volumetric flow rate of the reactant mixture by the surface area of the flame. If the mixture is fuel rich, another *non-luminous non-premixed* or *diffusion* flame surrounds the conical flame.

Premixed flames on Bunsen burner:

Bunsen burner flame photographs of methane air are shown in the figure for $\phi = 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3$, and 1.4. The temperature of the reactant mixture is kept at 298 K, and the operating pressure of the burner is around 1 bar. When the equivalence ratio is increased from 0.7 to around 1.05, the luminosity of the conical inner flame increases. When $\phi > 1.1$, the luminosity of the inner conical flame decreases. Luminosity is associated with flame temperature.