Course Name: Theory of Fire Propagation (Fire Dynamics)

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Week – 08

Lecture – 05

Module 6 – Analysis of Fire Plumes

Fire Plumes:

Flow fields in gaseous jet diffusion flames as well as fires established over condensed (liquid and solid) fuels are dominated by buoyancy forces of various degrees, induced by density differences. Density of a gas is inversely proportional to the temperature. In a flame or fire, steep temperature gradient, therefore, steep density gradient exists. Hotter gases rise upwards due to their relative lower density (caused by higher temperature) when compared to that of atmospheric air. Buoyancy-driven flow of hot gases established over a fire is often called a fire plume. It starts as a laminar flow and transitions to a turbulent regime, depending upon the strength and dimension of the fire.

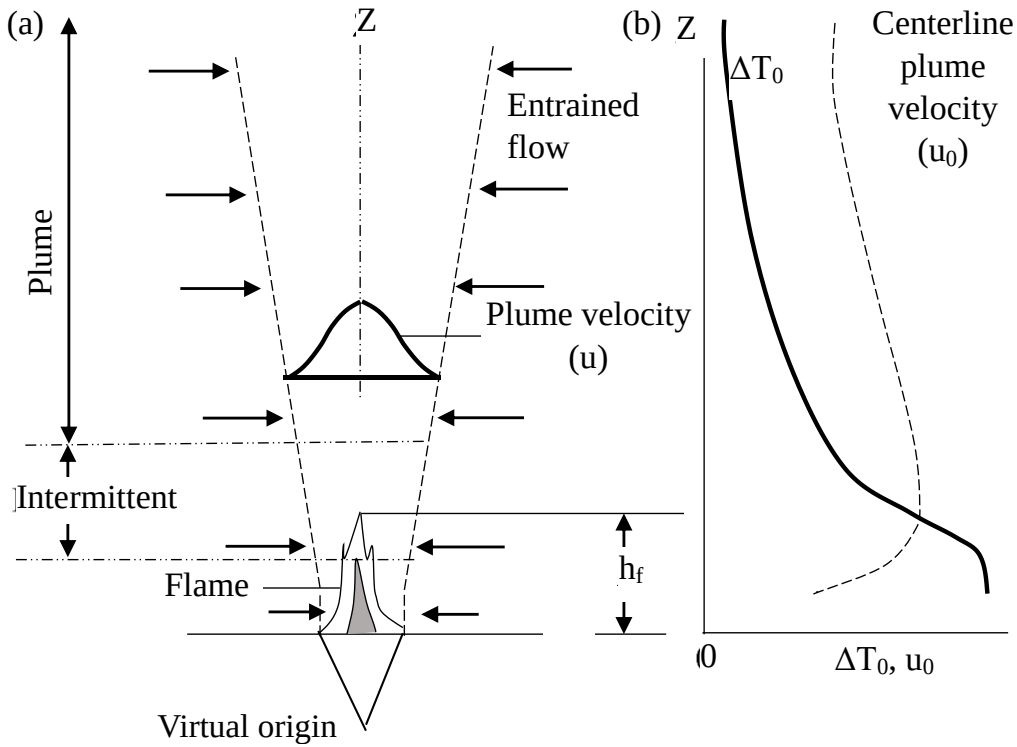
Fire plume characteristics:

Buoyancy force decreases as the density differences in the flow field decrease. This happens at a certain height. Temperature and velocity variations within this height characterize a fire plume. As hot gases rise upwards, cold atmospheric air and other gases **entrain** into the fire plume. The **entrainment** rate is another characteristic parameter of a fire plume. Entrainment is due to the fluid friction (viscosity) in laminar flows and predominantly due to the

action of the eddies in turbulent flows. Eddies of different scales are formed over the cold edges of the fire plume, and they affect the entrainment process significantly. Due to eddy dynamics, the fire plume is seen to be oscillatory.

Fire plume zones:

Fire plume has three zones (Heskestad, 1995 & Quintiere, 2017)



Heat release occurs in the flame zone near the fuel surface. This zone extends to an average flame height. Above this zone, an intermittent zone prevails. Here, the flame is seen intermittently. This zone encompasses the maximum flame length, which is almost twice the minimum flame height. Significant fluctuations are observed in this zone. Above this zone, only hot product gases exist, and it is called the plume zone. Flame height is determined by plotting a variable called intermittency, I, which is the ratio of the time for which a flame is present in a given location over the total time of observation. In the flame zone, the value of I is unity. In the intermittent zone, the value of I reduces sharply, and it is zero in the plume zone. The mean flame length is the axial location, where I = 0.5