Course Name: Theory of Fire Propagation (Fire Dynamics)

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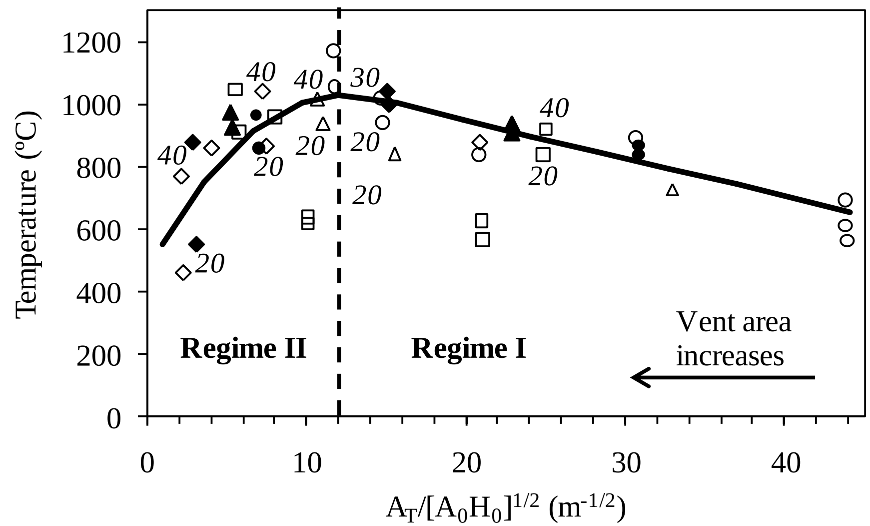
Week – 10

Lecture – 03

Module 7 – Enclosure Fires

Enclosure fires – duration and severity:



A_T = area of the enclosure without floor & openings.

A_0 = area of all the openings.

H_0 = height of the opening.

x-axis is called ventilation factor, $A_T/[A_0H_0]^{0.5}$.

In regime I of fully developed fires, flames are coming out of the vent and burning takes place both inside and outside, indicating that the quantity of air available inside the compartment is not sufficient to burn all the fuel generated. In Regime I, the burning rate is almost independent of the amount of fuel and its surface area and only proportional to the amount of air supply through the openings. Mass burning rate or severity increases linearly with ventilation factor (**$A_T/[A_0H_0]^{0.5}$**) till it reaches a value of ~12. After this, the burning rate is represented by a Regime II fire. In Regime II, burning is **dependent** on the quantity of fuel. Duration and severity of a compartment fire are thus dependent on which regime the burning behaviour lies.

Smoke movement in developing fire:

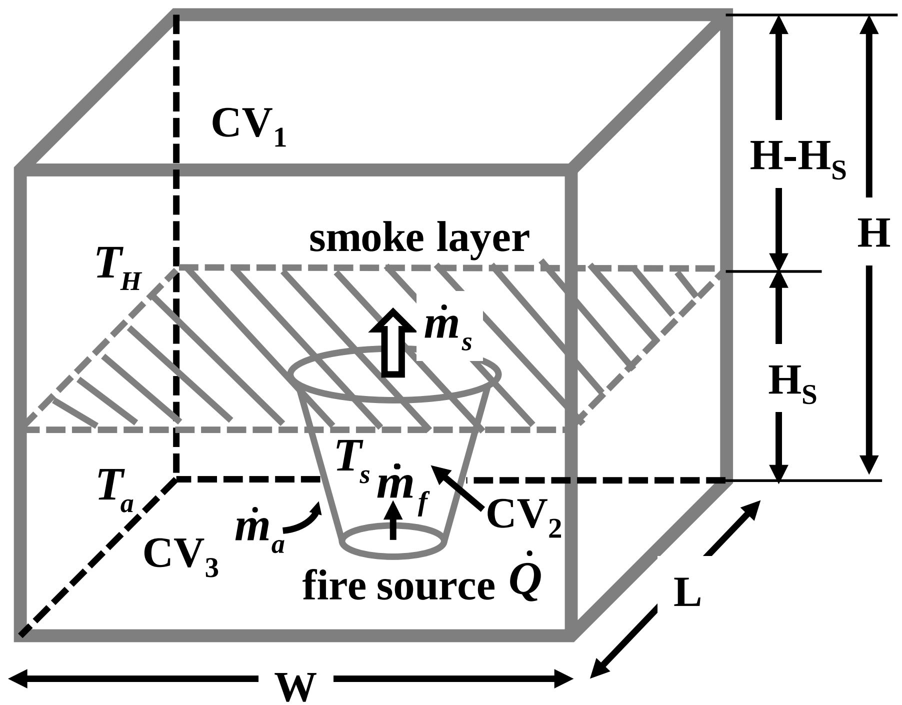
Figure shows filling of an enclosure (L × W × H) by smoke. Hot products (smoke) generates due to burning of fire source and the smoke accumulates at the top (in CV_1). Let H_S be the height of the accumulated smoke layer measured from the bottom.

Mass conservation in CV_1:

Here, $\dot{m}_a$ is mass flow rate of entrained air, $\dot{m}_f$ is mass loss rate of fuel and m_{CV_1} is mass of smoke in CV_1.

$$\dot{m}_a + \dot{m}_f = \frac{dm_{CV_1}}{dt}$$

Usually, $\dot{m}_f << \dot{m}_a$.



Smoke movement in developing fire:

Mass conservation in CV_1 is now written as:

$$\frac{dm_{CV_1}}{dt} = \frac{\rho_a T_a}{T_s(t)}(L \times W)\frac{d}{dt}[H - H_S(t)] = \dot{m}_a = E\left(\frac{g\rho_\infty^2}{c_p T_\infty}\right)^{\frac{1}{3}}(\dot{Q}_c)^{\frac{1}{3}}(H_S(t))^{\frac{5}{3}}$$

Assuming the total convective heat from the fire is delivered to the smoke, the energy balance on CV_1 is written as:

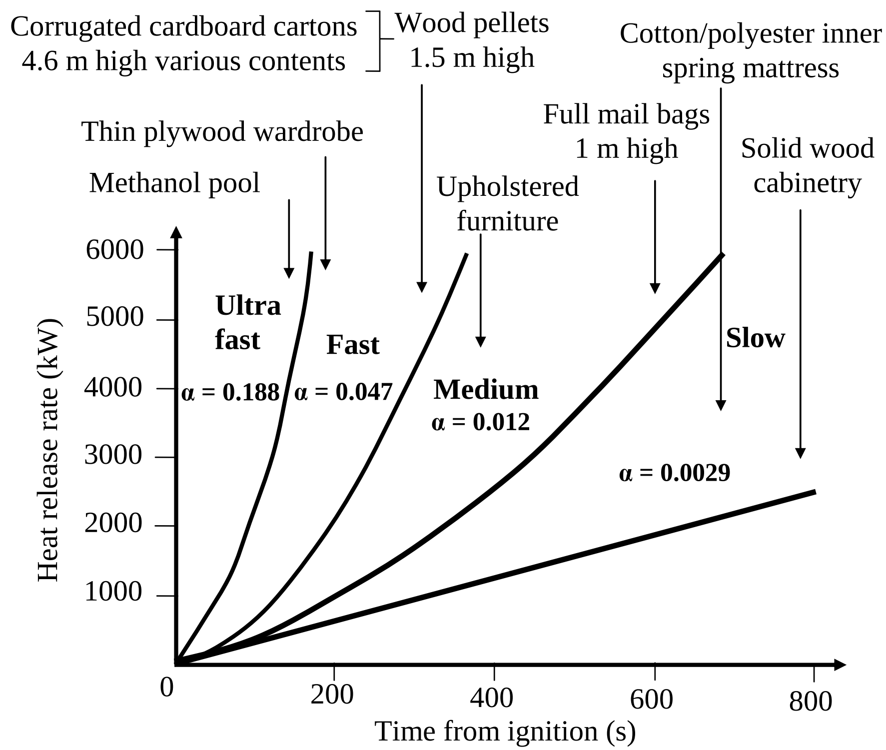
$$\dot{Q}_c(t) = \dot{m}_a c_p[T_S(t) - T_a] = E\left(\frac{g\rho_\infty^2}{c_p T_\infty}\right)^{\frac{1}{3}}(\dot{Q}_c)^{\frac{1}{3}}(H_S(t))^{\frac{5}{3}} c_p[T_S(t) - T_a]$$

$H_S(t)$ and $T_S(t)$ can be solved numerically from above equations, if the convective heat release rate, $\dot{Q}_c$ is known.

For steady fire, $\dot{Q}_c$ can be assumed a constant.

For unsteady fires, a growth rate is assumed: $\boldsymbol{\dot{Q}_c(t) = \alpha t^n}$.

Fire growth rate:



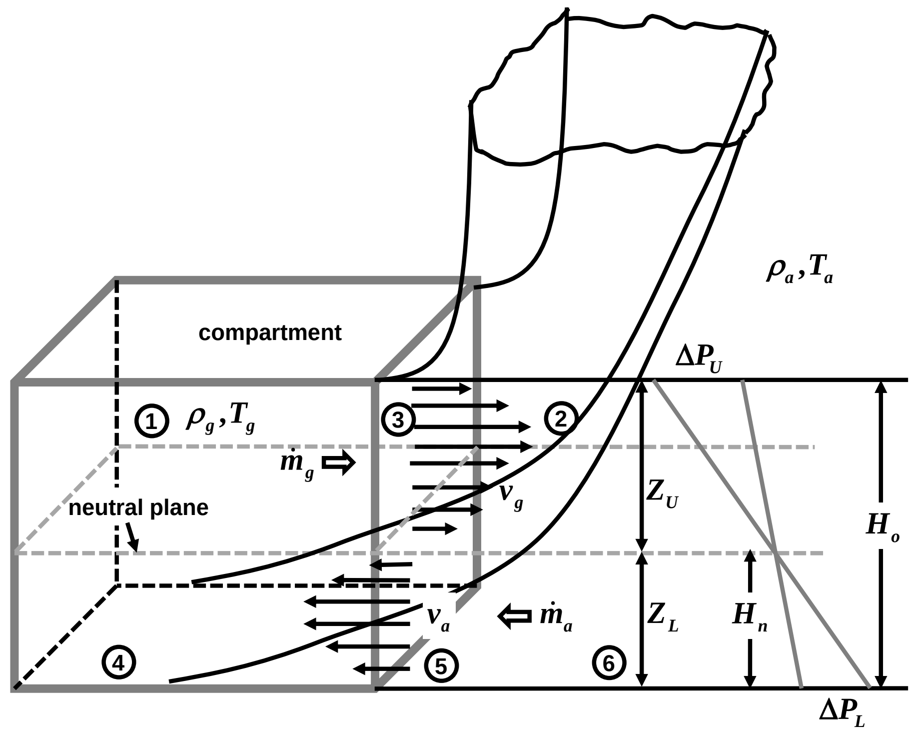
Growth rates of fire per standard codes (fitted power law)

Growth rate: $\dot{Q}_c(t) = \alpha t^n$.

In most cases, value of **n = 2**, as observed from experiments. Here, α (J/s^3) is based on material properties.

$$\alpha = \dot{m}''\pi V_f^2 \Delta H_C$$

In and out flow of gases from enclosure:



Flow of gases in & out of an enclosure during fully developed stage

H_0 = Opening height.

T_g = temperature of gases.

$\boldsymbol{\rho_g}$ = density of the hot gases.

$\boldsymbol{\dot{m}_g}$ = mass flow rate of hot gases out of enclosure.

$\mathbf{v_g}$ = velocity of hot gases flowing out of enclosure.

$\mathbf{H_n}$ = Neutral plane height, where $\Delta p = 0$.

Suffix a: Quantities related to air flowing into the enclosure.