Course Name: Theory of Fire Propagation (Fire Dynamics)

Professor's Name: Dr. V. Raghavan

Department Name: Mechanical Engineering

Institute: Indian Institute of Technology Madras, Chennai – 600036

Week – 02

Lecture – 02

Module 1 – Basics of Fires

Definitions

Fire detection and suppression:

Fire is detected using smoke detectors and CO sensors. These are usually located in the ceiling of a compartment. Smoke detectors are usually photo-electric-based devices. CO sensors are of electro-chemical or opto-chemical type devices. Once the fire is detected, devices such as sprinklers are activated. The time for detection depends upon a parameter called Response Time Index (RTI).

Fire suppression is achieved in three ways:

a) reducing the temperature of the flame and fuel surface,

b) diluting the oxygen or fuel to reduce their concentration, and

c) directly inhibiting the chemical reactions.

Sprinklers reduce the temperature and oxygen concentration. Foams are used in liquid fuel pool fires to inhibit the fuel vapors coming out of the pool surface. Agents such as halons directly inhibit the major oxidation reactions.

Flammability tests:

Flammability tests are carried out to evaluate several fire-related aspects of materials used in several applications. Tests for ignitability, flame spread rate, mass burning rate, and heat release rate are carried out.

Several standards, such as ASTM, provide procedures to carry out these tests.

[1] American Society for Testing and Materials: Fire and flammability standards https://www.astm.org/Standards/fire-and-flammability-standards.html

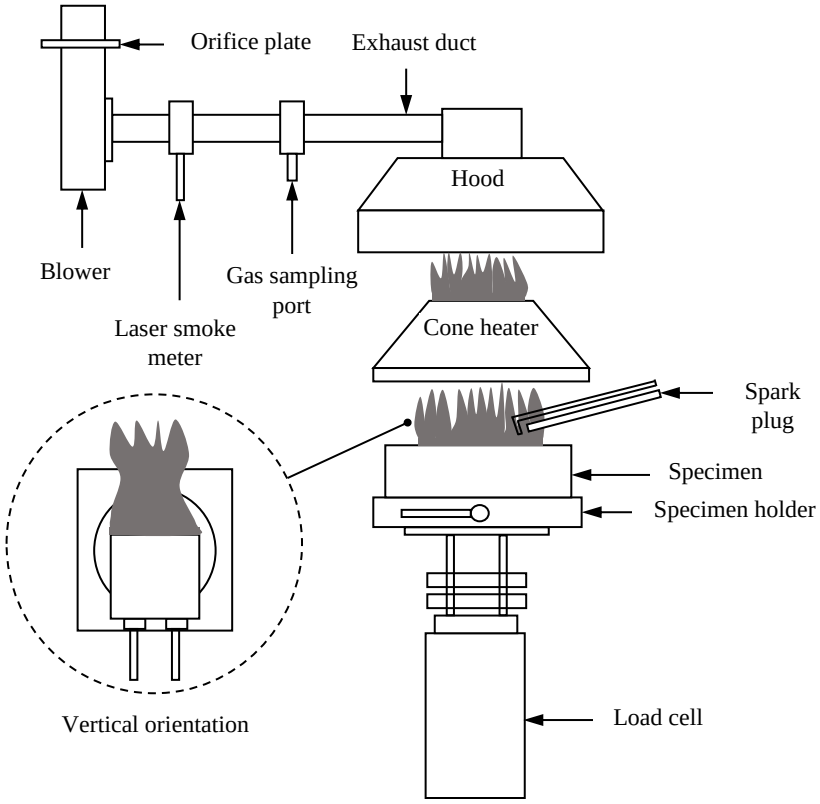
[2] National Fire Protection Agency (NFPA)

The apparatus commonly used for flammability tests are

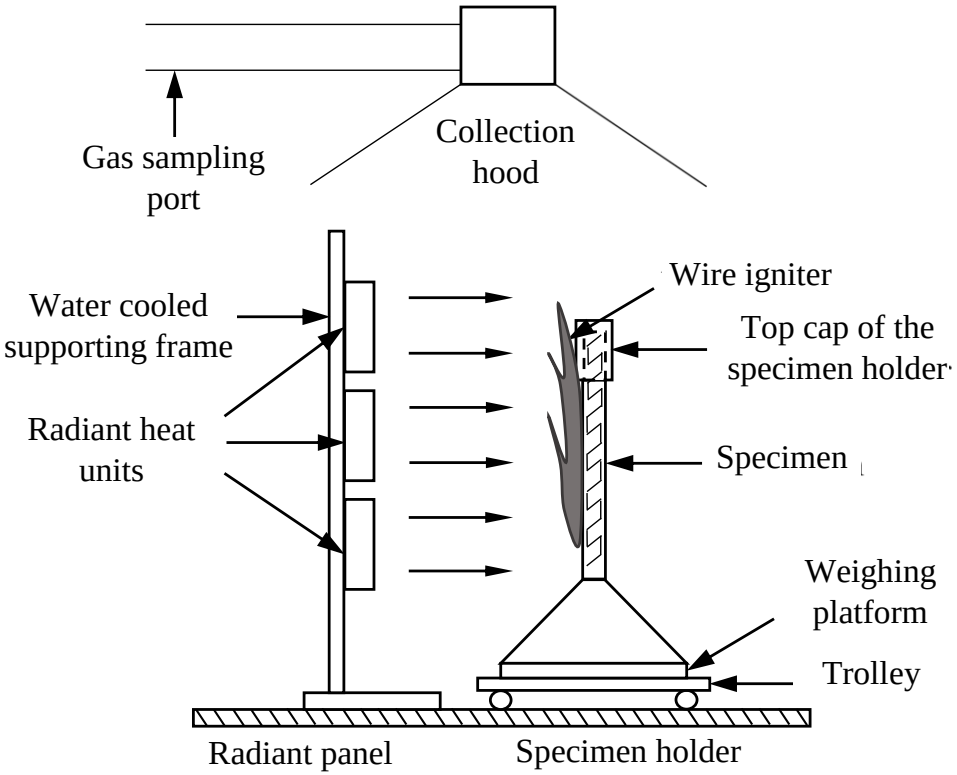
[1] Flame Propagation Apparatus (FPA), and

[2] Cone calorimeter (CC).

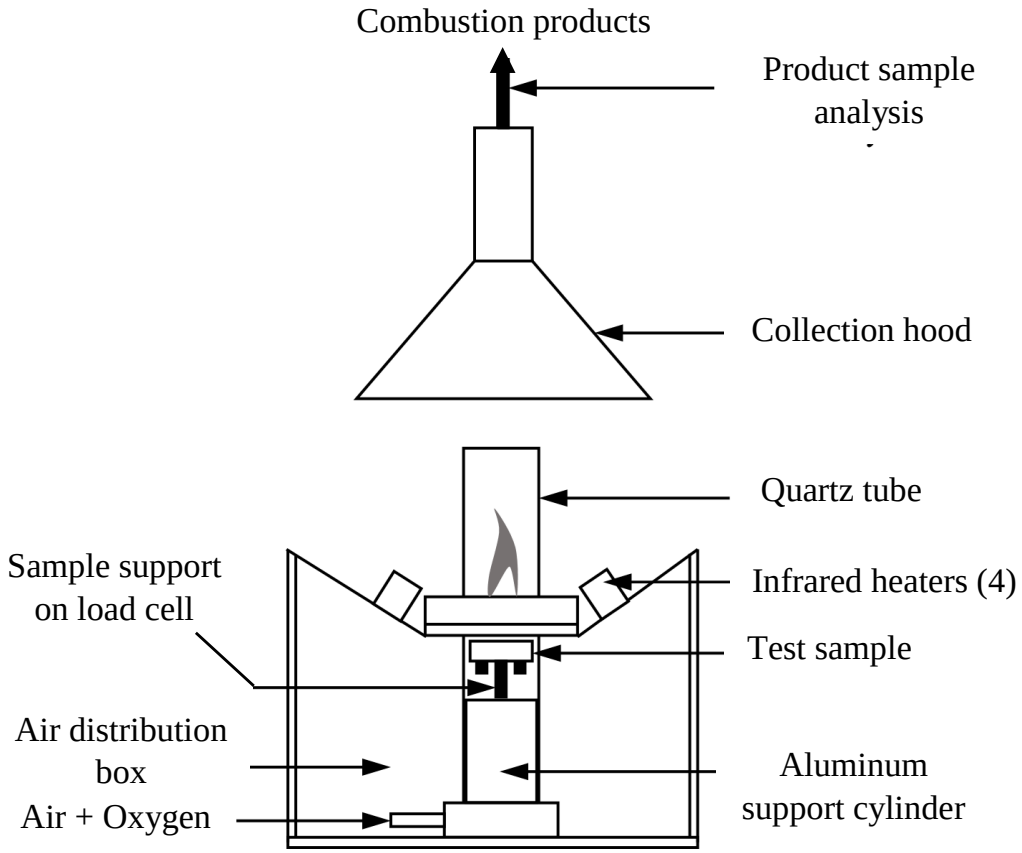
Cone Calorimeter:



Radiant Panel Test:



Fire Propagation Apparatus (FPA):



Ignition tests:

Ignition tests on FPA or cone calorimeter are conducted on materials by subjecting their surface to a certain heat flux and using a pilot igniter, such as a spark plug, at a given distance from the material's surface. The heat flux at which flaming ignition occurs is called critical heat flux. The temperature of the surface at which ignition occurs, is called ignition temperature. Thermal Response Parameter (TRP) is then defined using thermal inertia of the material and ignition temperature. An empirical correlation for time for ignition is obtained by using factors such as ignition temperature, critical and external heat flux values, a fraction of the critical heat flux that is lost to the ambient, and material thickness.

Heat of gasification or pyrolysis:

The heat of gasification (or pyrolysis) is determined using FPA using flaming and non-flaming approaches. Here, the mass loss rate is measured along with the values of heat flux to the surface (convective and radiative), re-radiation loss, and external heat flux, if any. Using these, the heat of gasification is determined. Heat of gasification is also correlated as a function of molecular mass. For several hydrocarbons having molecular mass in the range of 30 kg/kmol to 250 kg/kmol such correlations are available.

Flame Heat Flux:

Flame heat flux is measured using standard procedures in FPA or CC. Contributions of heat flux to the surface by convection and radiation are determined for various materials with varying surface areas burning in an ambience having varying oxygen concentrations. Convective heat transfer coefficient for the flow field in FPA is determined using combustion of simple fuel such as methanol. As the oxygen mass fraction is increased more than around 0.3, asymptotic behaviors in mass loss rate and flame heat flux are observed. Also, as the material surface area is increased,

the radiative contribution of flame heat flux increases and reaches an asymptotic value and convective contribution decreases.