UNIVERSITY OF MARYLAND
Department of Fire Protection Engineering

Compartment Fires

Stages of Fire Growth

- Growth Stage (Pre-flashover)
  - Fire Plume
  - Ceiling Jet
  - Smoke Layer
- Flashover
- Post-flashover

Stages of Fire Growth

- Fire development in a space is governed principally by
  - Fluid mechanics
  - Heat transfer
  - Thermodynamics

Growth Stage

- Localized fire: single item or limited number of objects burning in room.

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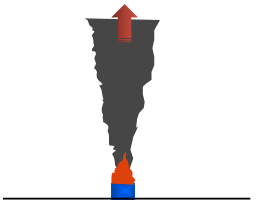
Fire Plume

- Buoyant column of flame & hot combustion products rising above the fuel



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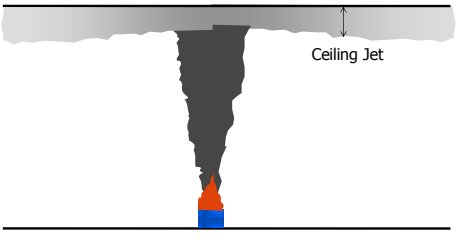
Ceiling Jet

- Transports heat/smoke to vicinity of ceiling-mounted spot detectors and sprinklers



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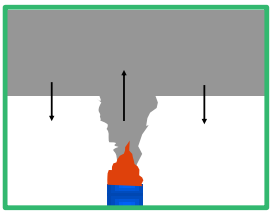
Smoke Layer



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Flashover

- Flashover Indicators
  - Temperature in ceiling layer > 540 ^{o}C
  - Heat flux at floor level > 20 kW/m^2
  - O_2 level immediately following 0-2%
  - Steep, brief pressure rise: > 25 Pa water column
  - Steep increase in CO production

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Flashover Prediction

- McCaffrey, Quintiere, Harkelroad (MQH) developed correlation based on theoretical analysis, used experimental data to
  - determine constants
  - confirm theory
- Experimental basis of MQH correlation
  - Small compartment: area: 0.16 to 12.0 m^2; height: 0.30 to 2.7 m
  - not very rapid fires
  - near cubical space: aspect ratio (L/W): 1.0 to 1.9
  - not severely ventilation limited
  - fire near middle of room

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Flashover Prediction

- Where:
  - ΔT: temperature of smoke layer (°C)
  - $\dot{Q}_f$: heat release rate (kW)
  - A_o: area of open door/window (m^2)
  - H_o: height of open door/window (m)
  - h_k: heat transfer coefficient of room enclosure = k/δ (kW/m^2-K)
    - k = thermal conductivity of enclosure (e.g. = 0.00017 kW/m-K for gypsum wallboard)
    - δ = thickness of enclosure material (m)
  - A_T: total internal surface area for room (m^2)

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Flashover Prediction

- How big of a fire is needed to cause flashover in a space?
- Solve temperature equation for heat release rate with ΔT = 600 °C
- Example:
  - Room size: 3 m x 5 m x 3 m (height)
  - Ventilation by open door: 0.9 m x 2.1 m (height)
  - Enclosure: 13 mm gypsum wallboard

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Post-flashover

- Near constant burning rate, governed by air flow
- Heat flux
  - at floor level: 60-80 kW/m^2
  - at ceiling level: 100-120 kW/m^2
- Smoke layer temperature: 800-1,100°C, dependent on:
  - height & area of ventilation openings
  - heat losses to enclosure

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Video

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Discussion Topic

- Referring to the video in slide 40, identify the time after flaming ignition when each of the following becomes evident:
  - Formation of visible fire plume
  - Formation of smoke layer
  - Flashover
- Returning to the example predicting the fire size needed to obtain flashover, what is the heat release rate needed for flashover if
  - The room is 4 m x 6 m x 3 m (height)

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Summary

- There are several stages of fire development
- These stages are dictated principally by physical processes.
- Early stages of fire development are very transient in nature.

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