Fire Dynamics
Ignition II

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Objectives

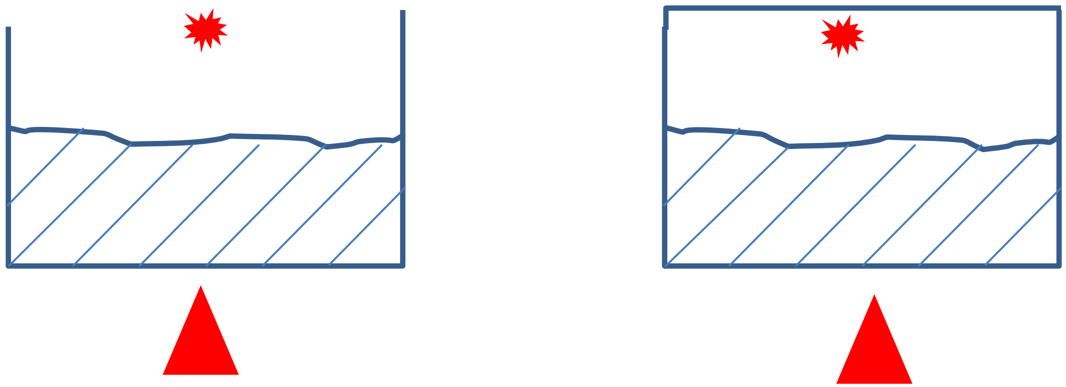
- Understanding Ignition phenomena for
  - Liquid
    - Flashpoint (=~minimum ignition liquid temp.)
    - Firepoint
    - AIT
  - Solid
    - Minimum ignition heat flux
    - Ignition time for thermally thin
    - Ignition time for thermally thick

Ignition of liquids

- Flashpoint: for flash flames
- Firepoint: for continuous flames
- Autoignition temp. (AIT)

Ignition of liquids

- Flashpoint: for flash flames
  - Open-cup flashpoint, closed-cup flashpoint



Ignition of liquids

- Flashpoint comparison

	Closed cup [ºC]	Open cup [ºC]
Mexican crude oil	19	35
Petrol	26.5	33.5
Tar oil	87	92.5
Toluene	4	7
Ethanol	13	22
Methanol	12	16

Ignition of solids for high $\dot{q}_e''$

- For thermally thin materials

$$t_{ig} \approx \rho c_p d \left(\frac{T_{ig} - T_{init}}{\dot{q}_e''} \right)$$

- For thermally thick materials

$$t_{ig} \approx \frac{\pi}{4} k \rho c_p \left(\frac{T_{ig} - T_{init}}{\dot{q}_e''} \right)^2$$

Properties of common materials

Material	T_{ig} (°C)	$k\rho c$ $((kW/m^2K)^2\ s)$
PMMA polycast, 1.59 mm	278	0.73
Polyurethane (535M)	280	—
Hardboard, 6.35 mm	298	1.87
Carpet (acrylic)	300	0.42
Fiberboard, low density (S119M)	330	—
Fiber insulation board	355	0.46
Hardboard, 3.175 mm	365	0.88
Hardboard (S159M)	372	—
PMMA Type G, 1.27 cm	378	1.02
Asphalt shingle	378	0.70
Douglas fir particle board, 1.27 cm	382	0.94
Wood panel (S178M)	385	—
Plywood, plain, 1.27 cm	390	0.54
Chipboard (S118M)	390	—
Plywood, plain, 0.635 cm	390	0.46
Foam, flexible, 2.54 cm	390	0.32
Glass/polyester, 2.24 mm	390	0.32
Mineral wool, textile paper (S160M)	400	—

Material	T_{ig} (°C)	$k\rho c$ $((kW/m^2K)^2\ s)$
Hardboard (gloss paint), 3.4 mm	400	1.22
Hardboard (nitrocellulose paint)	400	0.79
Glass/polyester, 1.14 mm	400	0.72
Particle board, 1.27 cm stock	412	0.93
Gypsum board, wall paper (S142M)	412	0.57
Carpet (nylon/wool blend)	412	0.68
Carpet #2 (wool, untreated)	435	0.25
Foam, rigid, 2.54 cm	435	0.03
Polyisocyanurate, 5.08 cm	445	0.02
Fiberglass shingle	445	0.50
Carpet #2 (wool, treated)	455	0.24
Carpet #1 (wool, stock)	465	0.11
Aircraft panel epoxy fiberite	505	0.24
Gypsum board, FR, 1.27 cm	510	0.40
Polycarbonate, 1.52 mm	528	1.16
Gypsum board, common, 1.27 mm	565	0.45
Plywood, FR, 1.27 cm	620	0.76
Polystyrene, 5.08 cm	630	0.38

Thermal inertia ($k\rho c$)

- Surface temperature for convective heating

$$\frac{T_s - T_{init}}{T_\infty - T_{init}} = 1 - \left[\exp\left(\frac{h^2 t}{k\rho c}\right)\right]\left[erfc\left(\frac{h\sqrt{t}}{\sqrt{k\rho c}}\right)\right]$$

- Low thermal inertia vs. high thermal inertia
  - Low thermal conductivity + low density + low specific heat → (fast or slow) surface temperature rise?

Thermal diffusivity ($\frac{k}{\rho c}$)

- Low thermal diffusivity vs. high thermal diffusivity
  - High thermal conductivity + low density + low specific heat → (fast or slow) overall body temperature rise?
- Ability to reach equilibrium to the environment
  - High thermal diffusivity will reach the equilibrium (fast or slow).

Class example I

- With LFL of 3 Vol%, what is the minimum piloted ignition temperature for ethanol at 25 °C and 1 atm?

Antoine Equation Parameters

$$\log_{10}(P) = A - (B / (T + C))$$

P = vapor pressure (bar)
T = temperature (K)

A=5.37229, B=1670.409, C=-40.191

Heat of Vaporization = 38.6 kJ/mole

Class example II

- Calculate time to ignite 1.27 cm thick plywood subject to 20 kW/m^2 radiant heat flux.
  - Thermally thick,
  - T_{ig} = 390 ^oC, T_{init}=20 ^oC
  - Density = 540 kg/m3
  - Thermal conductivity = 0.12 W/m-K
  - Specific heat = 2.5 J/g-K

$$t_{ig} \approx \frac{\pi}{4} k \rho c_p \left(\frac{T_{ig} - T_{init}}{\dot{q}''_e} \right)^2$$

Class example III

- Calculate the ignition temperature that satisfies the same ignition time for both thermally thick and thermally thin cases of the material with the following properties.
  - Thermal conductivity = 0.12 W/m-K,
  - Density = 510 kg/m3,
  - Specific heat = 1.3 J/g-K,
  - d = 1 mm,
  - Exposed heat flux = 15kW/m^2