Lecture 26

Premixed Flame Quenching, Flammability, Ignition.

Flame Extinction.

- Recall video: products/flame were cooled by Heat Transfer.
- Sprays : ΔH_{vap} → cools by Heat Transfer.
- Chemical Suppressants: Halogens alter kinetics (Suck up radicals)
  - use in place of sprinklers to avoid water Damage.
  - e.g. Computer facilities.

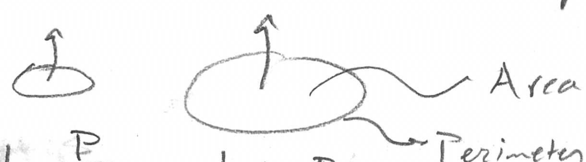
Quenching

- Flames propagate through passages → extinguish if passage is Small.

(Q) Main factors ?

→ Volumetric Heat release vs "Surface" heat Transfer.

→ Critical Diameter → Quenching Dist.



high $\frac{P}{A}$ low $\frac{P}{A}$

} Project to Vol, Surf Area.

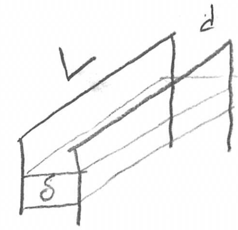
- Also Slots
- "Flame arrestors"
- $D_{Q,tube} \sim$ 20-50% higher than $D_{Q,slit}$

∞ Slit → $\frac{P}{A} = \frac{2}{D_s}$

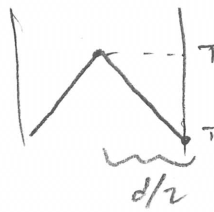
Circle → $\frac{P}{A} = \frac{1}{4D_c}$

→ $D_c = \frac{1}{8} D_s$

Quenching



- Quenching Distance: <u>Slot</u>
- Energy Balance:
  - Heat Release = Heat Transfer
  - Steady State at limit just before extinction.



$$\dot{Q}''' \cdot V = A q''$$

$$V = L d \delta$$

$$A = 2 L \delta$$

$$\dot{Q}''' = \dot{m}_F''' \Delta h_c$$

$$q'' = \lambda \left.\frac{dT}{dx}\right|_{wall} \approx \lambda \frac{T_b - T_w}{d/2} \approx \lambda \frac{T_b - T_w}{d/b}$$

$$\rightarrow \quad \dot{m}''' \Delta h_c \cdot \cancel{L} d \cancel{\delta} = \frac{2 \cancel{L \delta} \lambda b}{d} (T_b - T_w)$$

$$* \quad d^2 = (T_b - T_w) \cdot \frac{2 \lambda b}{\dot{m}''' \Delta h_c} \quad ;$$

$$\Delta h_c = (1+\nu) c_p (T_b - T_u)$$

$$F + \nu O_x \rightarrow (1+\nu) \text{ Prod}$$

Δh_c is $\frac{J}{\text{kg fuel}}$

$$d^2 = \frac{2 \lambda b \cancel{(T_b - T_u)}}{\dot{m}''' c_p \cancel{(T_b - T_u)} (1+\nu)}$$

$$d^2 = \frac{2b}{\dot{m}'''(1+\nu)} \cdot \frac{\lambda \rho_u}{\rho_u c_p} = \frac{2b\alpha}{\dot{m}'''(1+\nu)} \cdot \rho_u = 4b\alpha^2 \cdot \frac{2\rho_u}{2\alpha \dot{m}_F'''(1+\nu)}$$

$$= \frac{4b\alpha^2}{S_L^2}$$

$$\boxed{d = \cancel{2b} \frac{2\sqrt{b}\alpha}{S_L}} \quad \boxed{d = \sqrt{b}\, \delta}$$

Turns' S_L

Notes: $S_L \rightarrow d = \frac{\sqrt{2b}\alpha}{S_L} = \sqrt{2b}\, \delta$

our in-class S_L
Alternative.

- d increases with increasing α
- d Decreases with increasing S_L
- $d \propto \delta$

Q Do These make Sense?

Q How Does b Change w/ increasing α?

Ex · Methane, $P = 1$ atm, $\phi = 1$, $T_u = 300$ K.

$\rightarrow S_L = 40$ cm/s

$\rightarrow d = 2\sqrt{b}\left(2.26 \times 10^{-4} \frac{m^2}{s}\right) / 0.4 \text{ m/s} \quad = 5.65E^{-4} \cdot 2\sqrt{b} \text{ m}$

Table 8.4 $\rightarrow d = 0.0025$ m   w/ $\alpha = 3.24 \times 10^{-4}$, $b = 2.38$.

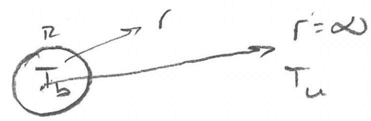
$\rightarrow b = 4.9$

Alternate $\rightarrow b = 9.8$

Note: b is unknown! $\rightarrow$ relations give order of magnitude of d, and functional form. $b > 2$ is True.

Ignition Energy

- Spherical Spark: Again at extinction limit.
- SS.



- Same Analysis.

$$\dot{m}_F''' \cdot \Delta h_c \cdot V = -\lambda \left.\frac{dT}{dr}\right|_R \cdot A$$

$$\dot{m}_F''' \cdot C_p\cancel{(T_b - T_u)}(1+\nu) \cdot \frac{4}{3}\cancel{\pi} R^3 = +\lambda \frac{\cancel{(T_b - T_u)}}{R} \cdot \cancel{4\pi} R^2$$

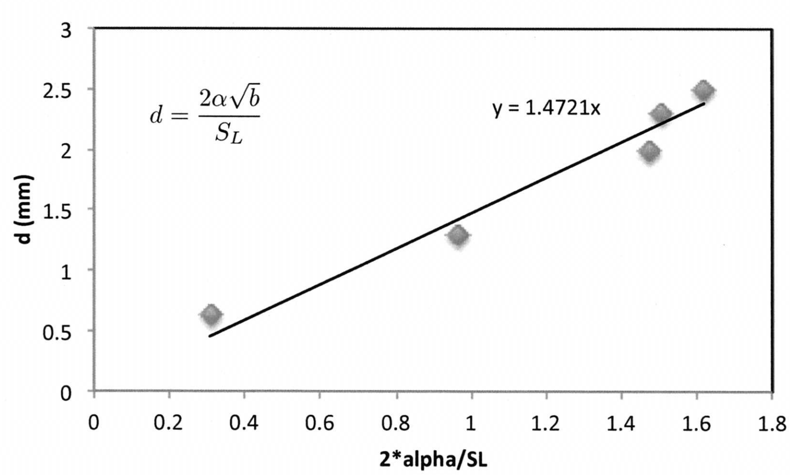
$$R_c^2 = \frac{3\lambda}{C_p(1+\nu)\dot{m}'''} \rightarrow R = \frac{\alpha\sqrt{6}}{S_L} \text{ as before.} \qquad = (\sqrt{6}/2)\,\delta$$

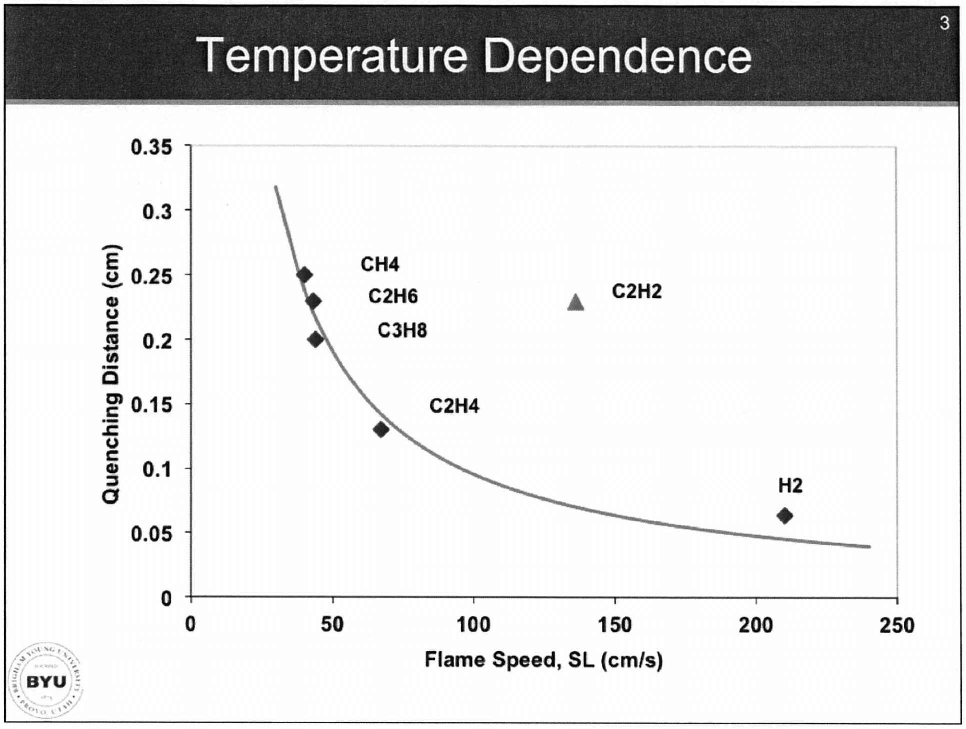
— $\rightarrow \left(\frac{\alpha\sqrt{3}}{S_L} \text{ alternative}\right) \qquad = \left(\sqrt{3}\,\delta \text{ alternative}\right)$

1

- Find unknown parameter b
- b scales the heat flux at the wall
- Is there one value?
- Use experimental δ, S_L to correlate b
- Use $d = \frac{2\alpha\sqrt{b}}{S_L}$
- Use average α
  - Each fuel at T_{ad}, 300 K
- Plot d vs $2\alpha/S_L$ → b = $(\text{slope})^2$ = 2.17
  - Force intercept = 0

2

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Temperature Dependence
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Quenching Distance (cm)
0
50
100
150
200
250
Flame Speed, SL (cm/s)
CH4
C2H6
C3H8
C2H4
C2H2
H2
BYU