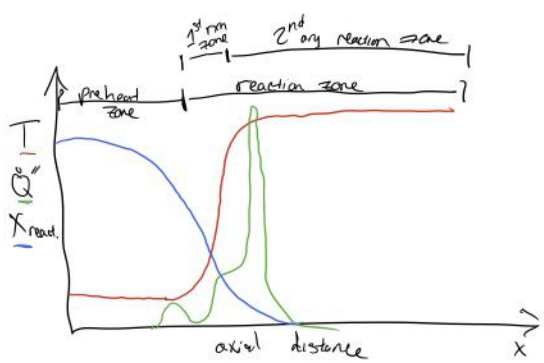
Laminar Premixed Flames

Monday, October 9, 2017 4:23 PM

Flame: a self-sustaining propagation of a localized combustion zone a subsonic velocities

* localized: - the flame occupies a small portion of the combustible mixture at any time
* Subsonic - $V_{sound} = 340$ m/s @ sea level
  - deflagration $< V_{sound}$
  - detonation $> V_{sound}$



Continuity : mass in = mass out

$$(\rho v A)_{in} = (\rho v A)_{out}$$

S_L = flame speed = speed of the unburned mixture

$$(\rho S_L A)_{in} = (\rho v A)_{out}$$

1-D flame

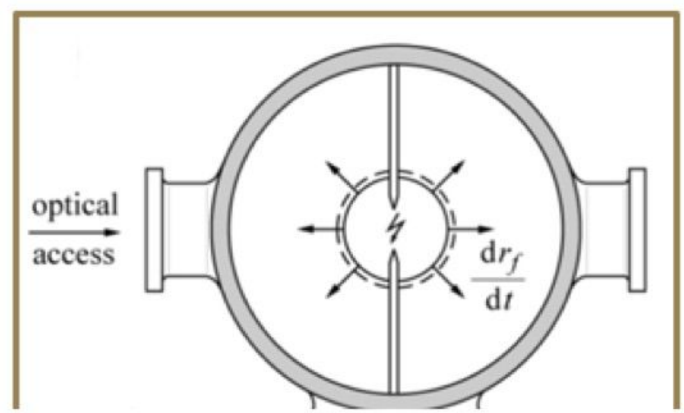
$A_{in} = A_{out}$

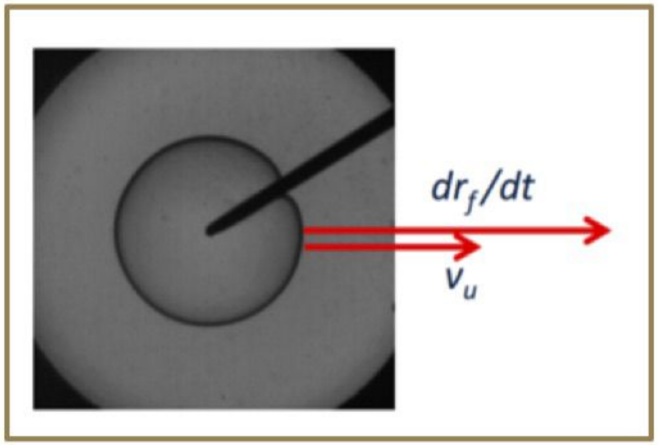
$\rho_{in/unburned} > \rho_{out, burned}$ $(T_{in} < T_{out})$

$V_{in/unburned} = S_L < V_{out, burned}$

$$\rho_u S_L A = \rho_B V_B A$$

* $CO + OH \rightarrow CO_2 + H$





Flame color:

hydrocarbon (C_xH_y)

color from high T reaction zone radiation:

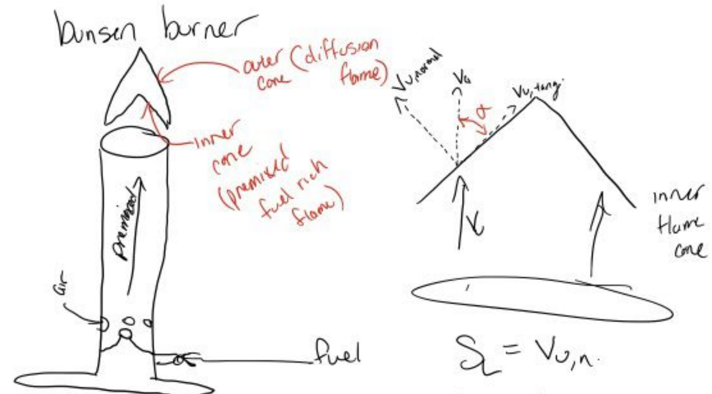
lean: blue flame! CH^*

Stoichiometric: blue-green C_2^*

rich: soot → black body radiation (yellow (almost white) to orange color)

OH^* & $CO + O \rightarrow CO_2 + h\nu$
↳ chemiluminescence

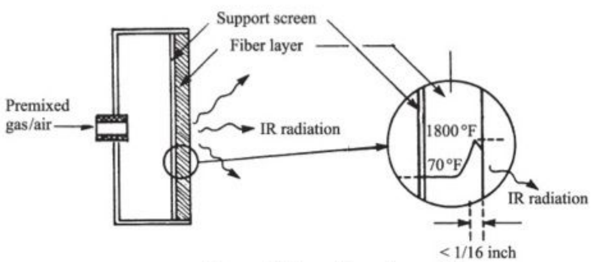
Types of burners:



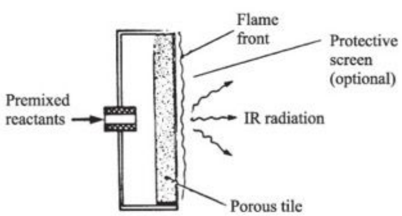
$S_L = V_{u,n}$

$S_L = V_u \sin\alpha$

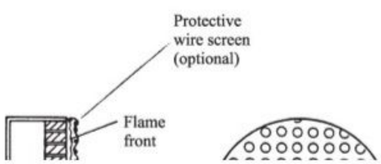
[Bunsen Burner - Periodic Table of Videos]

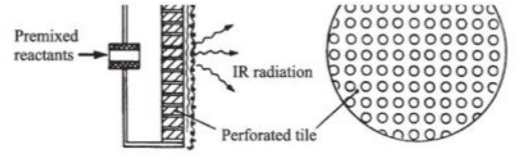


Fiber matrix burner (ceramic or metal)



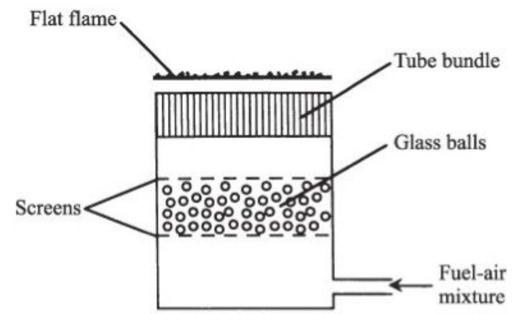
Porous ceramic foam burner



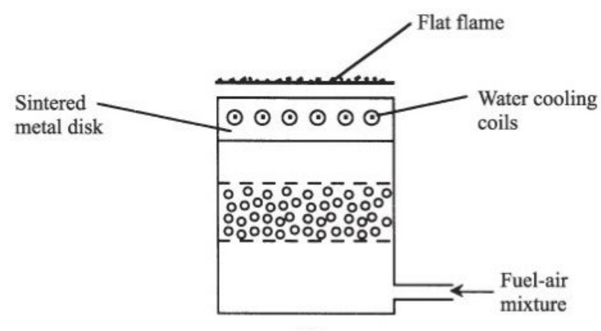


Ported ceramic tile burner

Figure 8.4 Direct-fired radiant burners provide uniform heat flux and high efficiency.
SOURCE: Reprinted with permission from the Center for Advanced Materials, *Newsletter*, (1), 1990, Penn State University.



(a)



(b)

Figure 8.5 (a) Adiabatic flat-flame burner. (b) Nonadiabatic flat-flame burner.

Simplified Flame Analysis

Assumptions:

1) 1-D, constant A, steady flow
2) KE, PE, viscous shear work & thermal radiation all ignored
3) Small P differences across the flame ignored (P = const.)
4) heat & mass diffusion are governed by Fourier's & Fick's laws: Binary Diffusion assumed.

Fouriers: $\dot{Q}''_x = -k \frac{dT}{dx}$

Ficks: $\dot{m}''_i = \dot{m}'' Y_i - \rho D \frac{dY_i}{dx}$