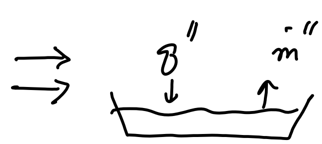
10/25/2010

This Lecture

* Review of Liquid Evaporation/Ignition
* Introduce Solid Ignition

SUMMARY OF LIQUID EVAP & IGNITION

Review



surface balances & also control vol. balances.

surface balances $q'' \downarrow$ $\uparrow \dot{m}'' h_{vap}$

$\downarrow q''_{cond}$ $\uparrow \dot{m}'' h_{liq}$

$$q'' = \dot{m}'' h_{fg} + q''_{cond}$$

↑ external h.t. ↑ mass transfer ↑ heating of liquid

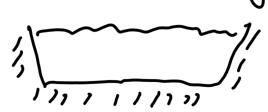
species balance.

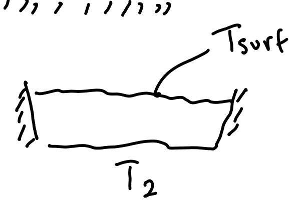
$$\dot{m}'' = \underbrace{h_m (Y_{surf} - Y_\infty)}_{\text{diffusive transport.}}$$

We know that unknowns are Y_{surf} & T_{surf}.
Combination of Newton's Law cooling & mass transfer eqn.

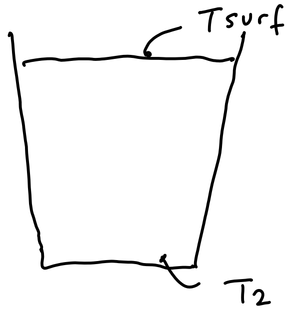
(a) $\Rightarrow$ $\underline{h(T_\infty - T_{surf}) = h_m (Y_{surf} - Y_\infty) h_{fg}}$ + $\underset{\text{deep pools.}}{\underline{q''_{cond}}}$

Three Limiting Cases.

(1)  shallow well insulated pool. $q''_{cond} = 0$

(2) 

$$q''_{cond} = h_{Liq}(T_{surf} - T_2)$$

③ 

deep pool $\quad q''_{cond} = \dot{m}'' c_p (T_{surf} - T_2)$

The trivial case occurs when you assume that T_{Liquid} is known.

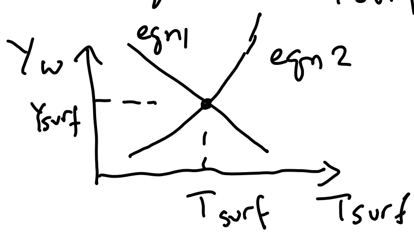
$\Rightarrow \quad T_{liq} = T_{HOT,\ surface}$

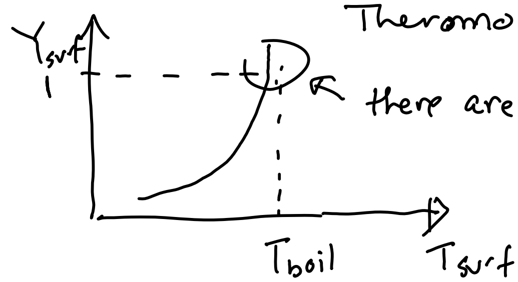
We Need to understand the more complex cases.

eqn. 1 $\quad T_{surf} = f(Y_{surf})$ $\quad$ abstraction of Eqn Ⓐ

eqn 2 $\quad T_{surf} = g(Y_{surf})$ $\quad$ Clausius Clapyron eqn

Theromo relationship.





there are errors near T_b & $Y \approx 1$

<u>2 Hard Problems</u>

- You can use chapter 3 analysis to compute or characterize Y_{mix}

couple evaporation analysis to conservation eqns.

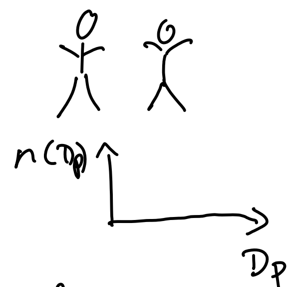
$$\frac{dm_i}{dt} = \dot{m}_f Y_{i,o} - \dot{m}_T Y_{i,mix} \qquad w/ \; m_i = m Y_{i,mix}$$

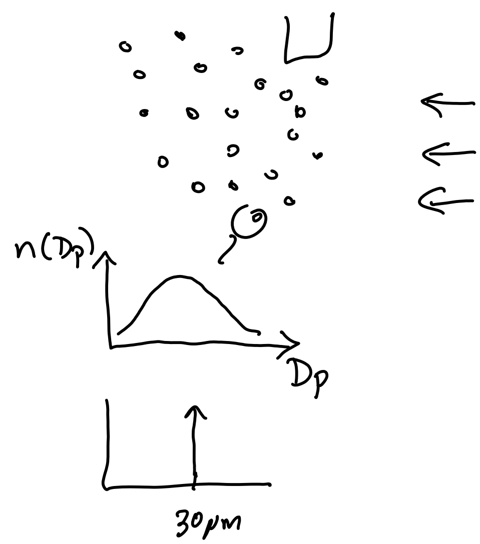
rate of mass flow of $Y_{i,0}$ is taken from

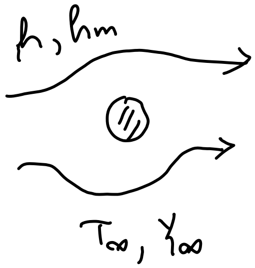
$$\dot{m}''_f \equiv h_m(Y_{surf} - Y_{i,mix})$$

use the coupled h & m transfer problem to add to the analysis.

Applications of this type of analysis.







$$\frac{dm}{dt} = -\dot{m}'' 4\pi R^2$$

$$\dot{m}'' \equiv h_m(Y_{surf} - Y_\infty) \quad \& \text{ C.C.}$$

$$q'' = h(T_\infty - T_{surf})$$

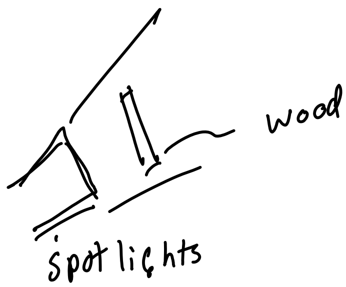
Small droplets & particles are covered in a part of fluid mechanics called low Re flow.

$Nu_D = 2$ when you solve the eqn you get the D^2 law.

$$\frac{d\left(\frac{4}{3}\pi R^3 \rho_e\right)}{dt} = -\dot{m}'' 4\pi R^2$$

$$\frac{dR}{dt} \propto \frac{C}{R} \qquad R^2(t) \sim ct \qquad \boxed{R^2 = R^2(0) - Kt}$$

TRANSITION TO SOLID IGNITION

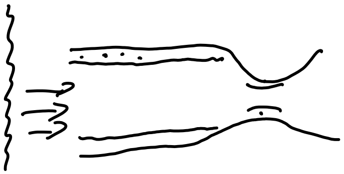


What types or levels (magnitudes) of heat flux will promote solid ignition.

Solid ignition heat fluxes are in the range $10 \frac{kW}{m^2} \to 20 \frac{kW}{m^2}$.

Typical Heat Fluxes:

Solar irradiance	$1\ kW/m^2$	
Ignition cellulosic mat'ls	$10\ kW/m^2$	(long time)
Fast ignition	$20\ kW/m^2$	
Fully involved room on fire	$75 - 150\ kW/m^2$	
Flame quenching	$500\ kW/m^2$	
In-cylinder SI engine	$500 \frac{kW}{m^2} - 5000 \frac{kW}{m^2}$	
Thermal Protective System	$10 \frac{MW}{m^2} - 20 \frac{MW}{m^2}$	
Rocket Nozzles (solid propellant)	$20 - 50 \frac{MW}{m^2}$	



$$\dot{q}'' \approx \varepsilon \sigma \left(T^4 - T_{surr}^4\right) \quad w/ \quad \dot{q}'' \approx 10^4 \ W/m^2 \ , \ \sigma = \underbrace{\ }_{5.67 \times 10^{-8}} \frac{W}{m^2 K^4}$$

& find T? $\qquad \varepsilon = 1$

Two types of externally driven solid ignition.

piloted — hot gas phase source

glowing

intermediate step of hot spots on the solid.