2nd Prof. P J Paul Memorial Combustion Researchers Meet

24-25 Jan. 2015, Chennai

Pool Fire Studies on Free-board Influence

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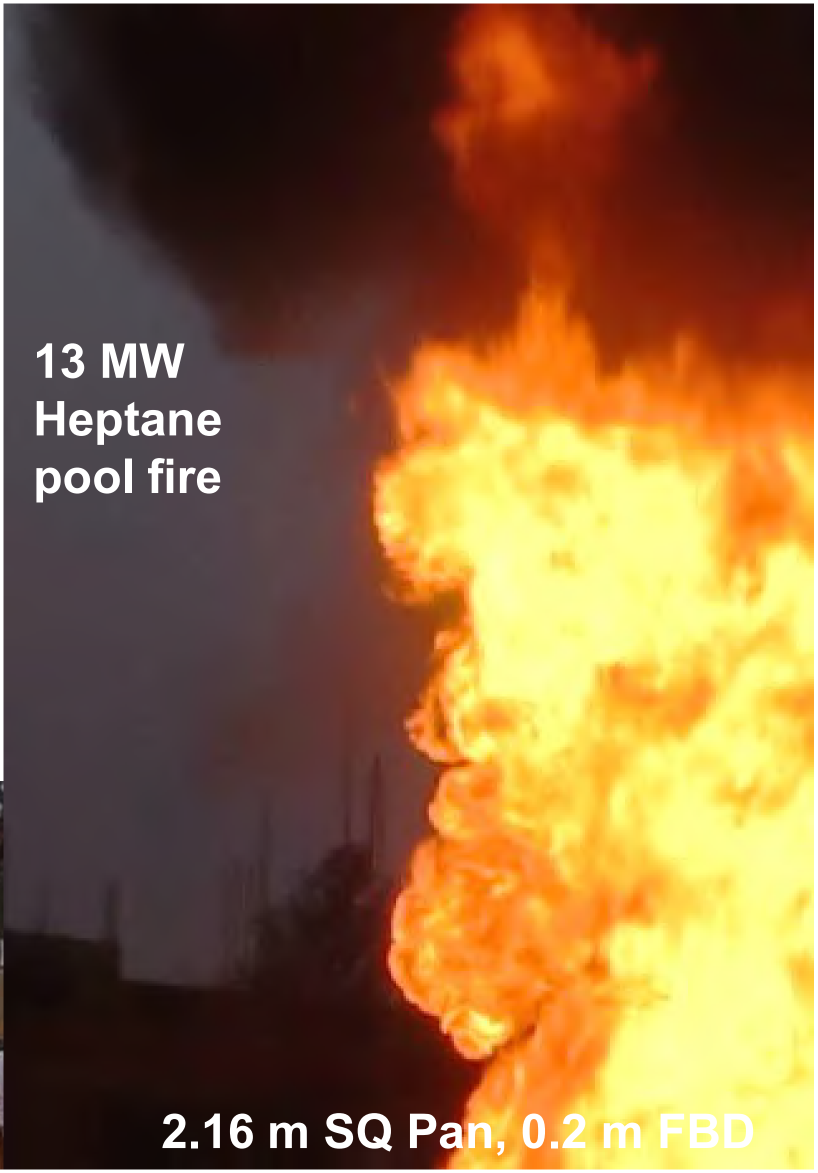
Pool Fires

- Pool fires are used for various testing purposes
- A large literature data base available on pool fire studies
- Pool fire burn rate is a function of pool size
- Wall conduction is dominant in small pools while radiation is dominant in large pools

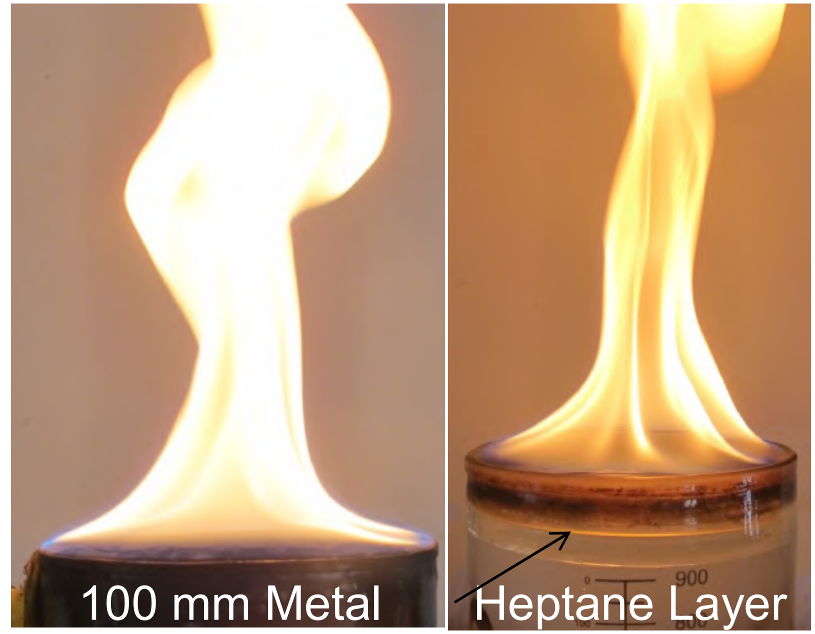


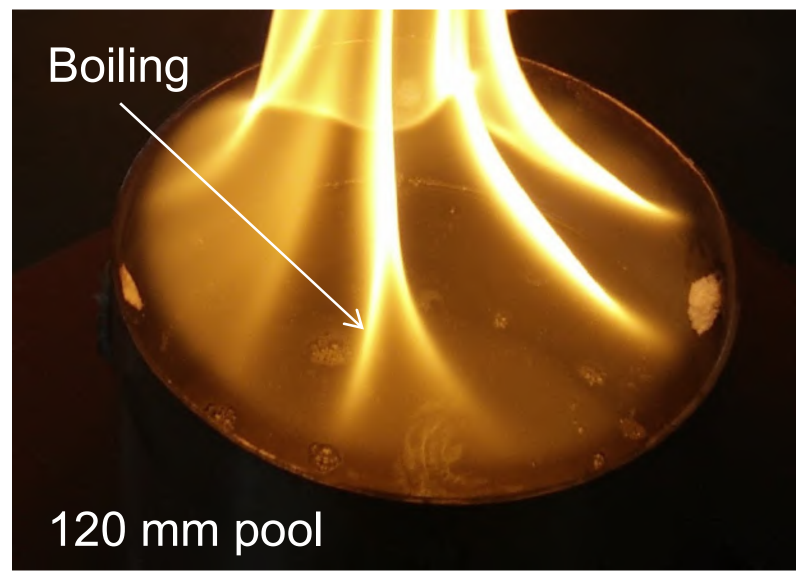
Pool Fires

- Pool fire research data available for pool fires operated in several modes: fixed/diminishing fuel level, Liquid fuel filled pan / fuel floated on water, const pan wall T / const. water T, Thin/thick fuel layers, Hydrocarbons/Alcohols
- Researchers have examined questions related to behavior of pool fires like: Dependence of burn rate on pool dia., Importance of wall conduction, Effect of initial T of fuel, Effect of nature of fuel on radiative feed back etc.,
- Questions related to thermal balance at fuel surface: power received to fuel surface from fire and wall conduction balanced by power lost through evaporation and conduction to liquid beneath is challenging as it involves quantification energy recd from fire
- **A study conducted at CDM for quantification of relative imp. of wall conduction on burn rate of n. Heptane is presented here**

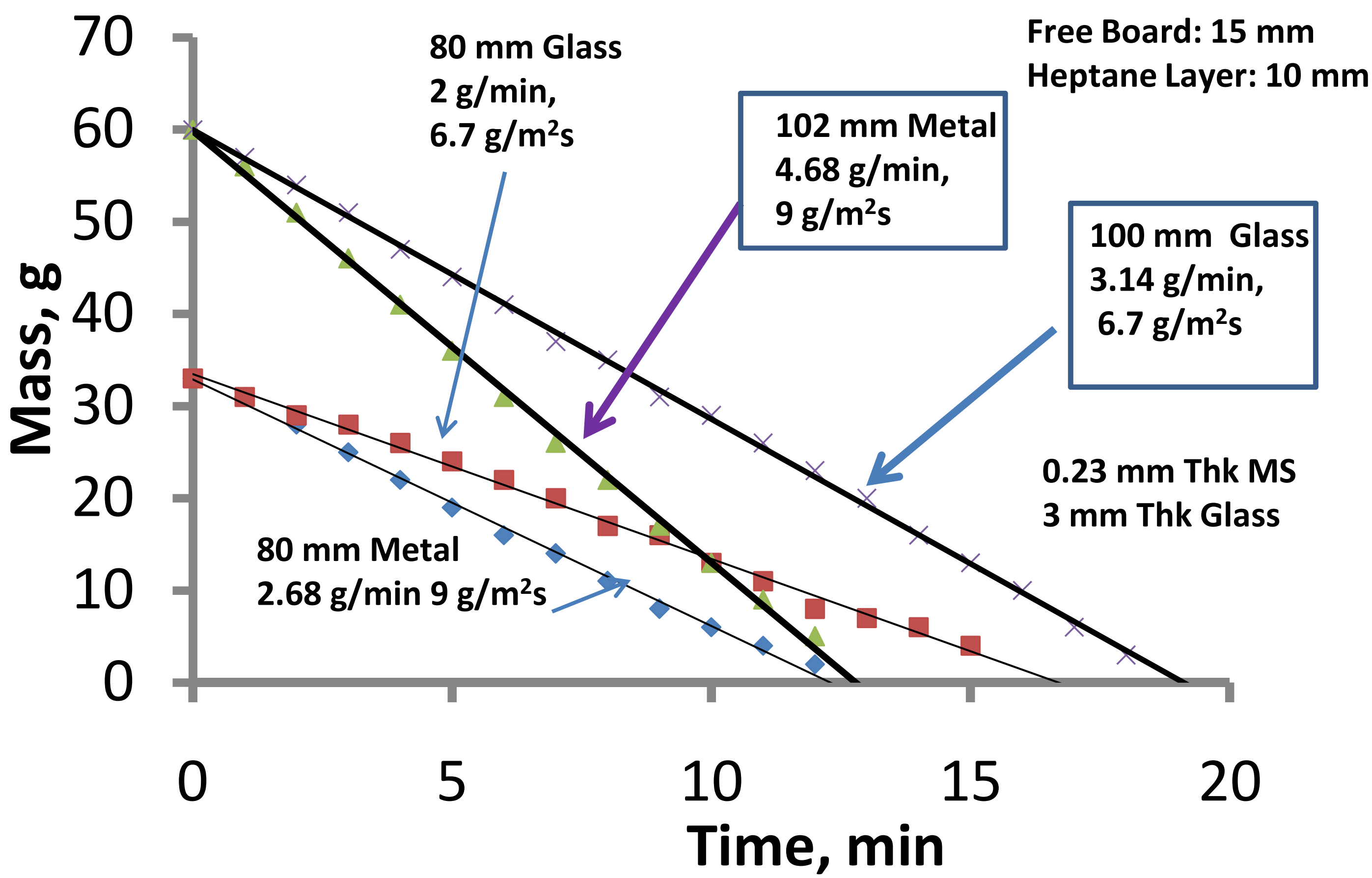
Small Pool Fire Experiments

- Heptane floated on water used as fuel in all Expts reported
- Expts were with diminishing fuel levels
- 10 mm fuel layer and 15 mm free board used unless stated otherwise
- In Small pool fire Expt.s at dia < 100 mm fuel surface never boiled even at burn durations > 30 min
- At pool dia 120 mm boiling surface boiling inception at about 4 min with vigorous boiling at 12 min
- All Expts conducted in quiscent draft free room





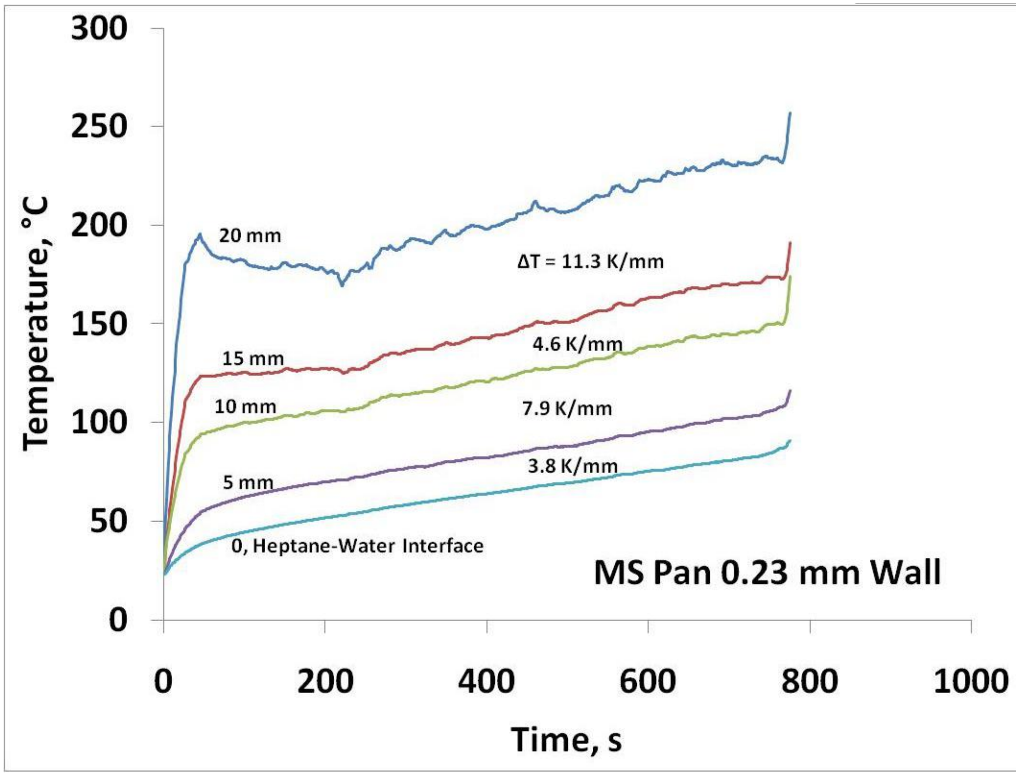
Fuel mass Comparisons

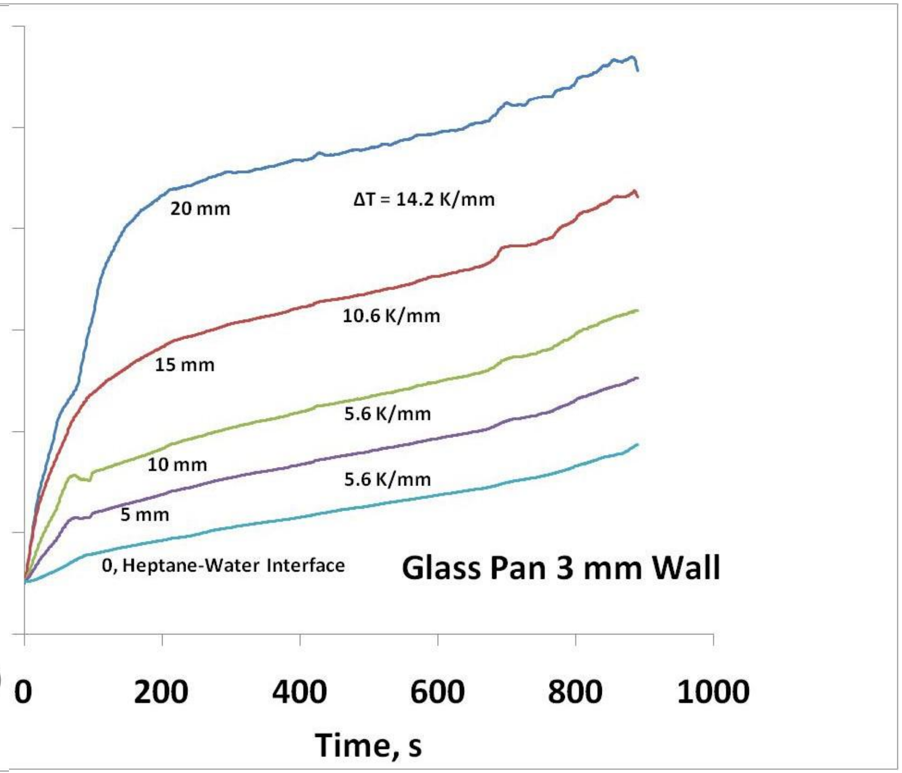


- Fuel mass flux is independent of dia in this range
- Wall has significantly altered burn rate

Wall T Histories: Metal & Glass Pans

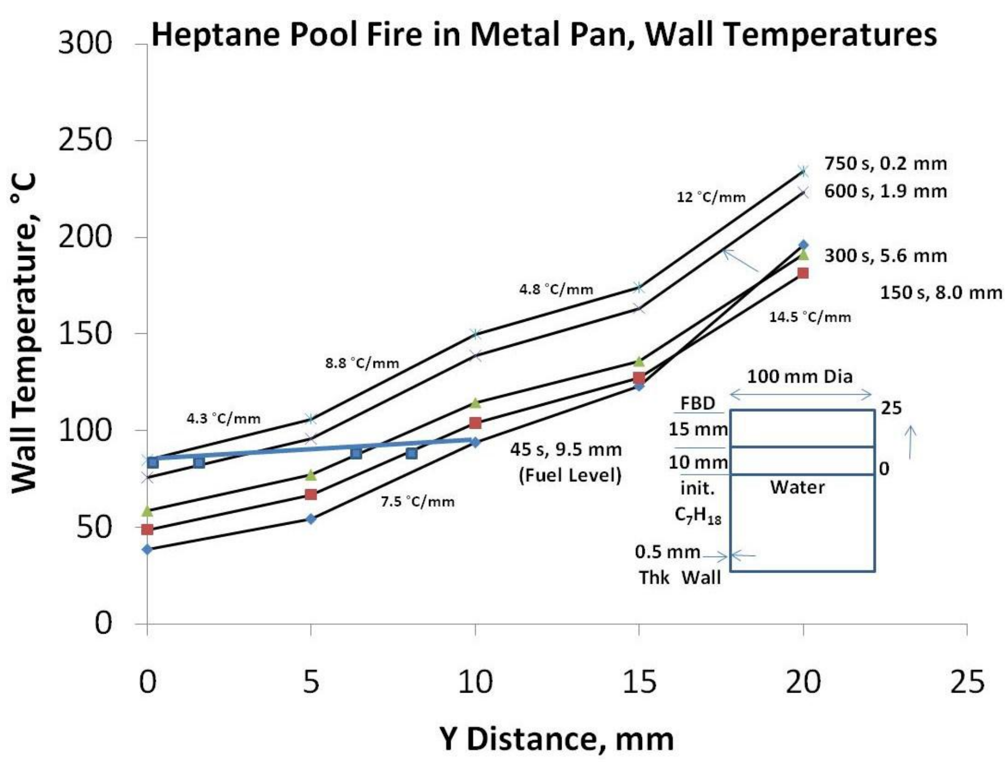
- Wall T rise is in 2 stages: preheating and steady rise
- Metal pan reaches steady phase in~ 30 s while glass pan reaches steady phase in ~ 200 s

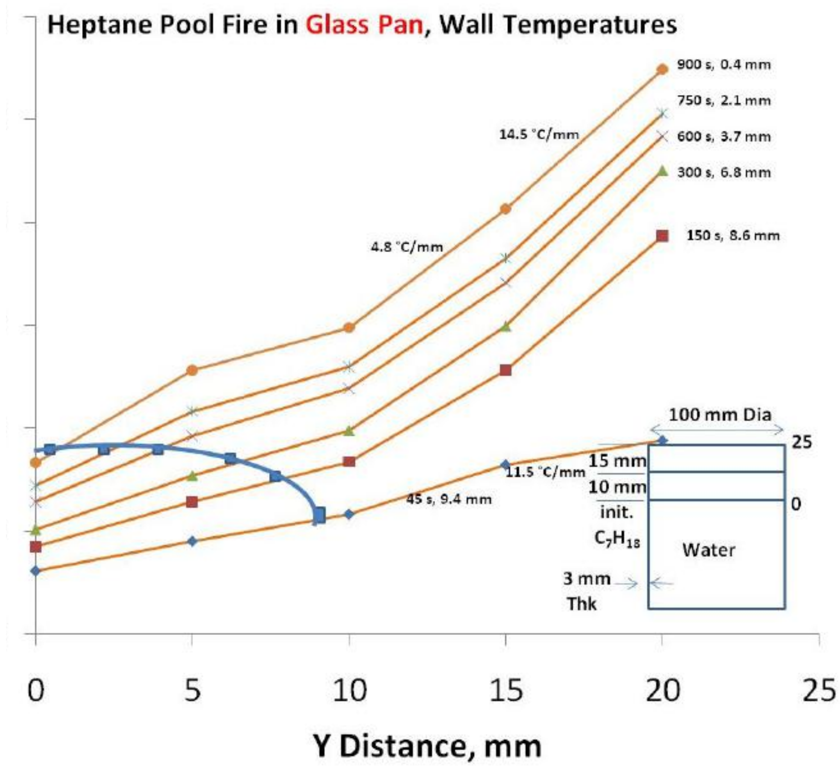




Wall T Profiles

- 100 mm dia in metal & glass pans with simul. acquisition of mass and Wall T
- It is seen that metal pan fuel surface T is const. while in glass pan fuel surface T is seen to increase with time
- Fuel surface tracked by mass remaining and assumed density

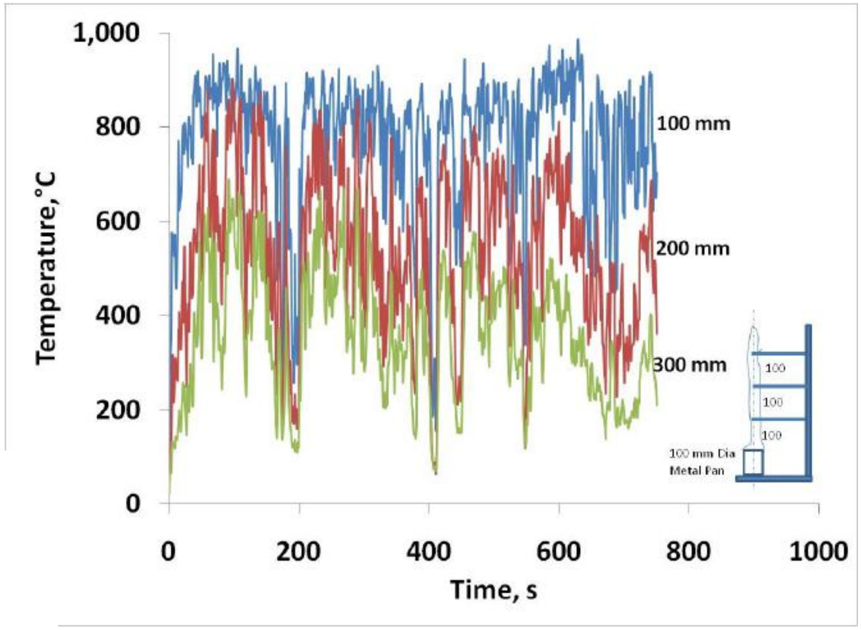


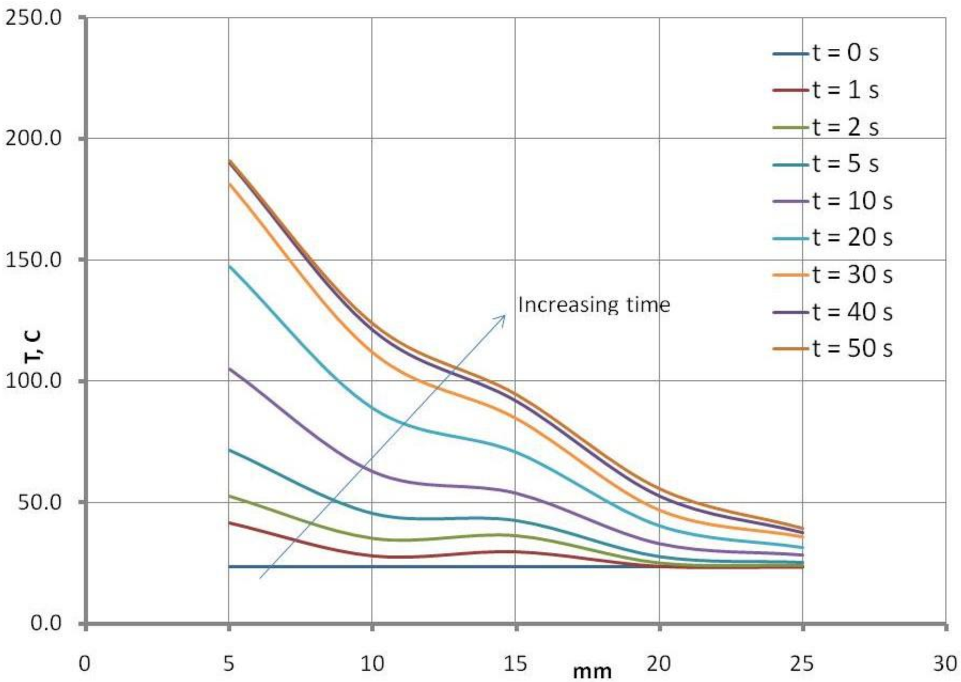


Wall T Profiles & G Phase T

- g-phase T at flame axis recorded for 100 mm pool at distances D, 2D & 3D from initial fuel surface

- Repeat expt.s have produced similar results



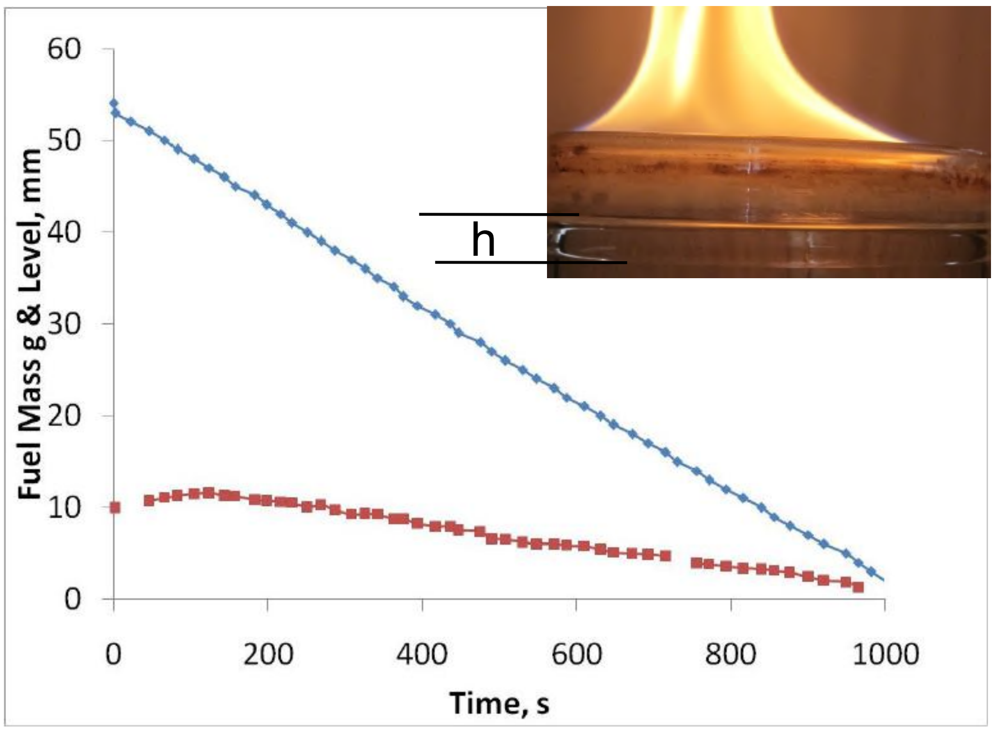


The temperature profile after ~ 30 s is about the same.

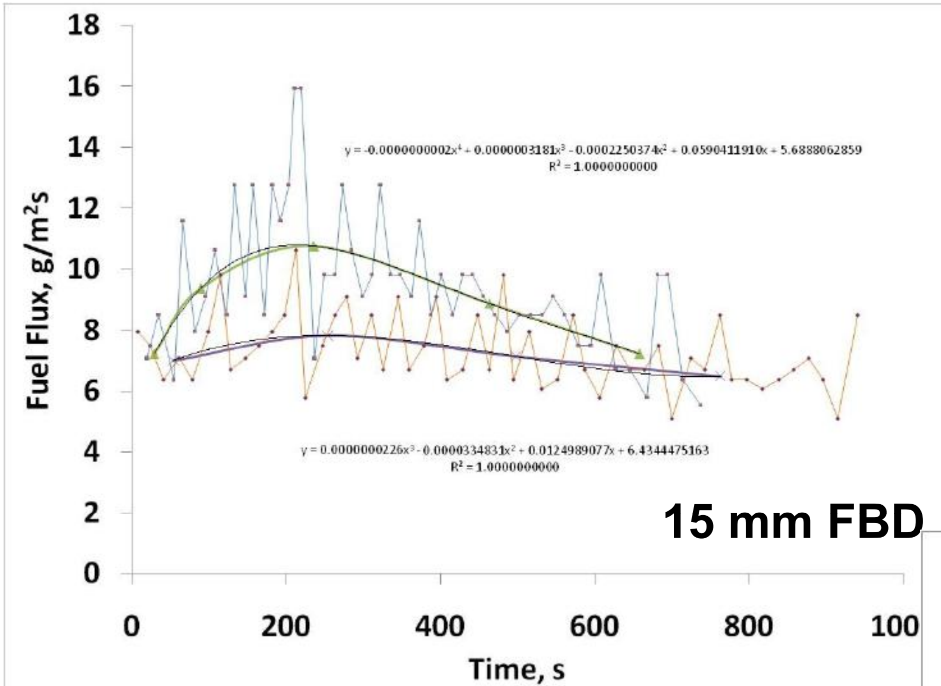
If we note that the burn time is 900 s. this is just a transient.

Effect of fuel layer expansion

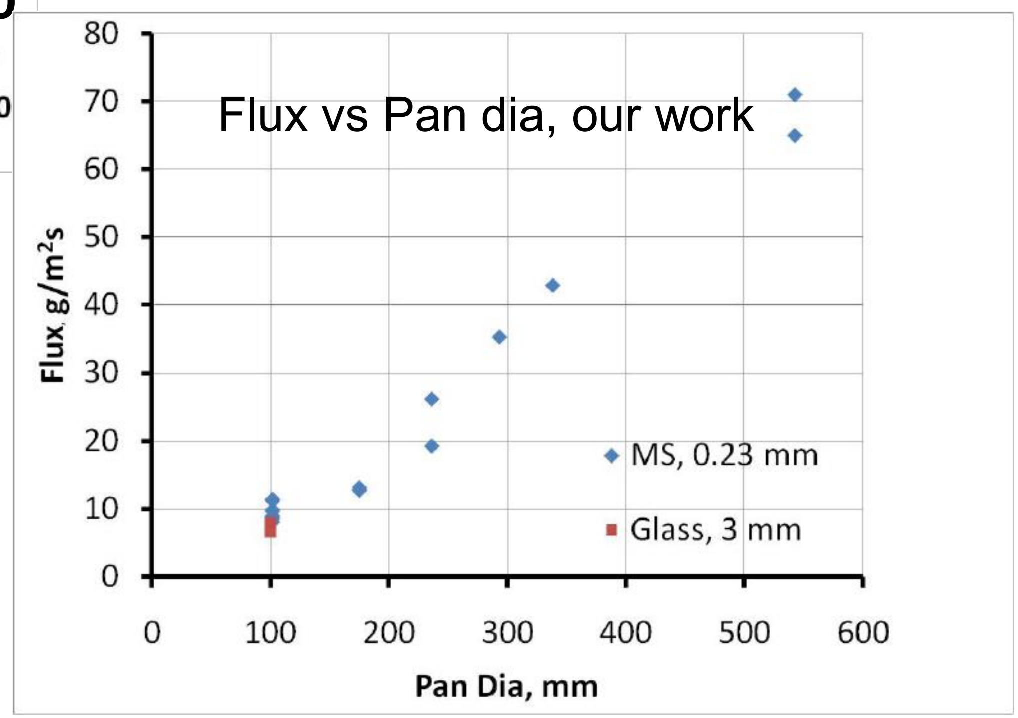
- Heptane layer swells due to decrease in density resulting from preheating. Using Hi res photos of fuel layer free board was determined at every g mass loss in glass pool
- FBD has decreased by 9% in 200 s after ~10% mass loss.



Flux Comparisons; Metal & Glass Pans



- Flux history of glass and metal pans have shown increase in flux for about 30% mass loss
- Subsequently fluxes are nearly same in both cases



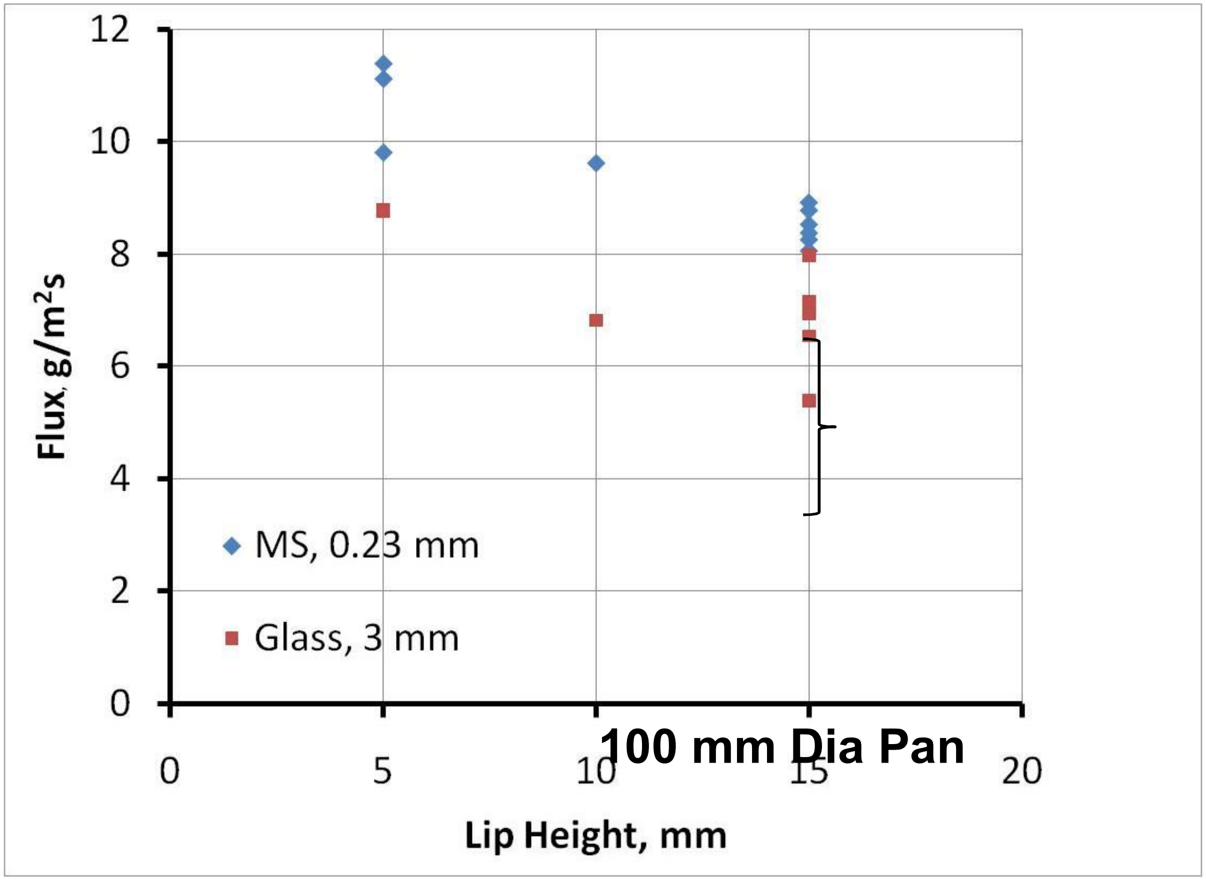
- Expts conducted at pan sizes from 70 mm to 540 mm
- Flux range of 6 to 72 g/m^2s recorded

Lip Height Influence

Increasing FBD has resulted in reduced fuel flux

Flux in metal pan is consistently higher than glass pan

Glass pan has recorded large variations in fuel flux



Heat Feedback

$$\dot{Q} = k\pi D(T_f - T_s) + hA_s(T_f - T_s) + \sigma F A_s({T_f}^4 - {T_s}^4)(1 - e^{-K_{ex}D})$$

Conduction **Convection** **Radiation**

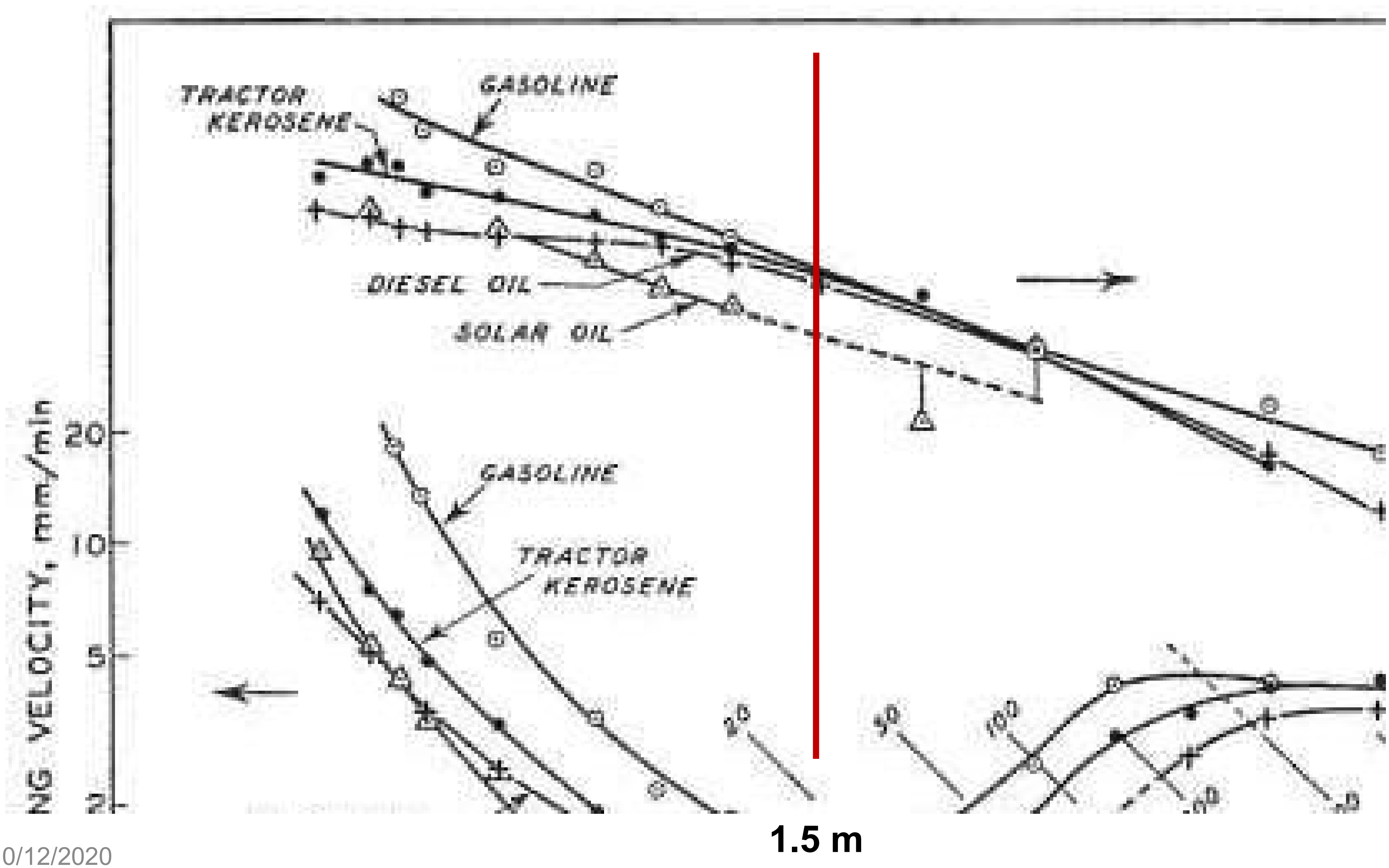
For small D conduction dominates as Conv. & Rad. are ppnl to D^2

For Large D Rad. dominates as it is ppnl to T_f^4 and $K_{ex}D$ is large

Hottel has analyzed Blinov Khudyakov experimental data and has presented burn rate correlation

Hottel’s correlation plot indicative (next slide) of const. burn rate beyond 1.5 m pan dia contrary to literature data

Hottel's Correlation



Modeling pool fire burn rate

$$\rho_l \dot{r}(\pi d_p^2/4)[L_s + c_{pl}(T_s - T_0)] = f(view)(\pi d_p^2/4)[1 - e^{-}$$

Power absorbed by Fuel

Radiant Power, W

Cond.Power, W

~1.1 - 1.3, Enhanced HT as Fn of burn rate

The eqn is recast as:

$$\dot{r} = \frac{C_2[1 - e^{-K_{ex} d_p}]\sigma T_f^4}{\ldots} + \frac{4 t_m k}{\ldots}$$

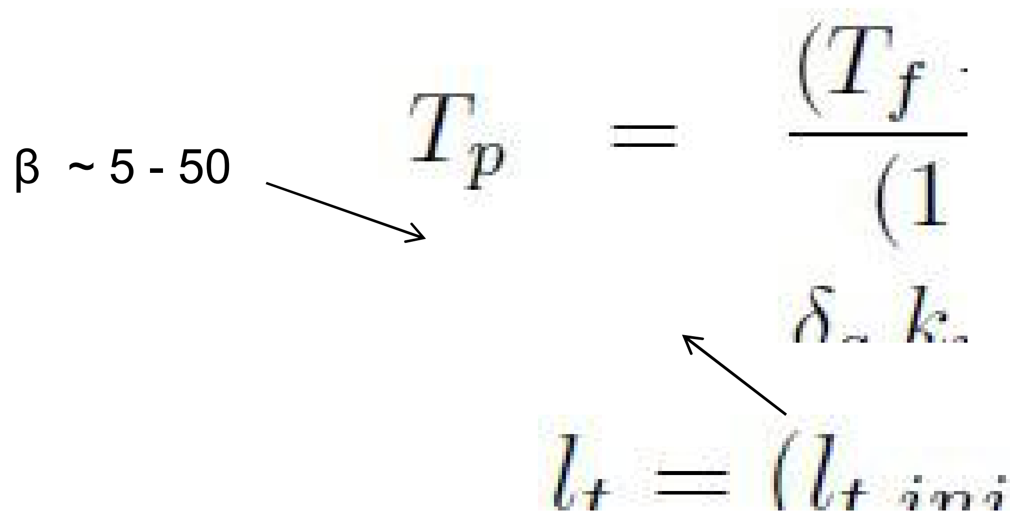
T_p obtained from quench dist considerations:

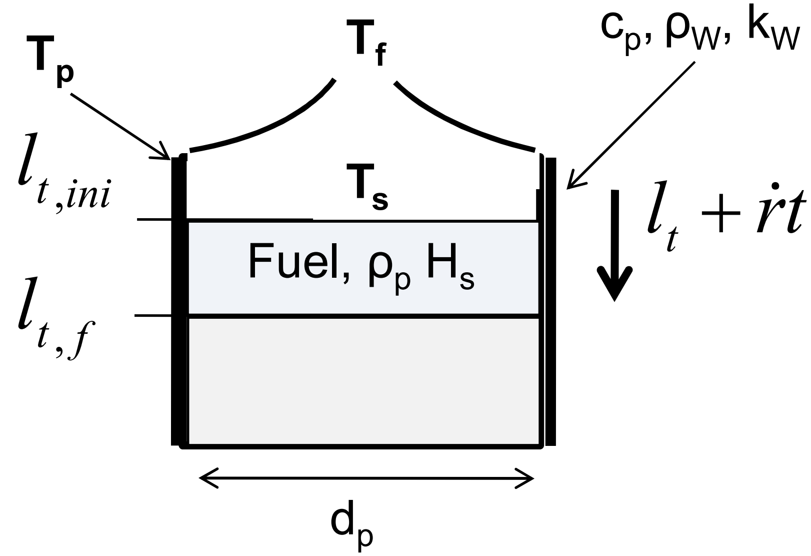
$$k_m \frac{dT_p}{dy} = k_m \frac{(T}{} \quad (T$$

~0.8 to 1 mm

200 K/mm
(venkatesh et al meas.)

Modeling pool fire burn rate





T_p estimated and used in burn rate equation Iterative procedure used with init. estimate of burn rate from only radiant flux term corrected for lip conduction

Modeling Burn time, t_b

$$\rho_p \dot{r} H_s = \dot{q}''_r + k_w \frac{T_p - T_s}{l_t} \frac{4T_w}{d_p}$$

Evap. flux **Rad. flux** **Cond. flux**

$$\int \dot{r} dt = l_t - l_{t,ini}$$

Integrating with respect to t,

$$\rho_p (l_{tf} - l_{t,in}) H_s = \dot{q}''_r \, t_b + \frac{4k_w t_w}{d_p} \frac{T_p - T_s}{(l_{tf} - l_{t,ini}) \ln\left(\frac{l_{tf}}{l_{t,ini}}\right)} t_b$$

$$\frac{\delta_q}{l_{t,ini} + \dot{r}t} \frac{k_w}{k_g}$$

$$t_b = \frac{\rho_p (l_{tf} - l_{t,in}) H_s}{\dot{q}''_r \, t_b + \frac{4k_w t_w}{d_p} \frac{T_p - T_s}{(l_{tf} - l_{t,ini}) \ln\left(\frac{l_{tf}}{l_{t,ini}}\right)}}$$

$$t_b = \frac{\left(\frac{l_{tf}}{l_{t,in}} - 1\right)}{\frac{\dot{q}''}{\rho_p H_s l_{t,ini}} + \frac{4k_w t_w}{\rho_p H_s d_p l_{t,ini}^2} \frac{T_f - T_s}{(1+\beta)\left(\frac{l_{tf}}{l_{t,ini}} - 1\right)} \ln\left(\frac{l_{tf}}{l_{t,ini}}\right)}$$

$$t_b = \frac{\left(\frac{l_{tf}}{l_{t,in}} - 1\right)}{\frac{\dot{q}''}{\rho_p H_s l_{t,ini}} + \frac{4k_w t_w}{\rho_p H_s d_p l_{t,ini}^2} \frac{T_p - T_s}{\left(\frac{l_{tf}}{l_{t,ini}} - 1\right)} \ln\left(\frac{l_{tf}}{l_{t,ini}}\right)}$$

β is slowly varying function of time and for mean values of β burn time can be estimated

Flux from Burn Time

$$Fuel\ flux = \frac{\rho_p l_t}{t_b} = \frac{\dot{q}''}{H_s} + \frac{4t_w}{d_p}\frac{k_w}{c_{pg} l_{tf}}\frac{c_{pg}(T_f - T_s)}{H_s(1+\beta)} \ln\left(1 + \frac{l_{tf}}{l_{t,ini}}\right)$$

$$B = \frac{c_{pg}(T_f - T_s)}{H_s}$$

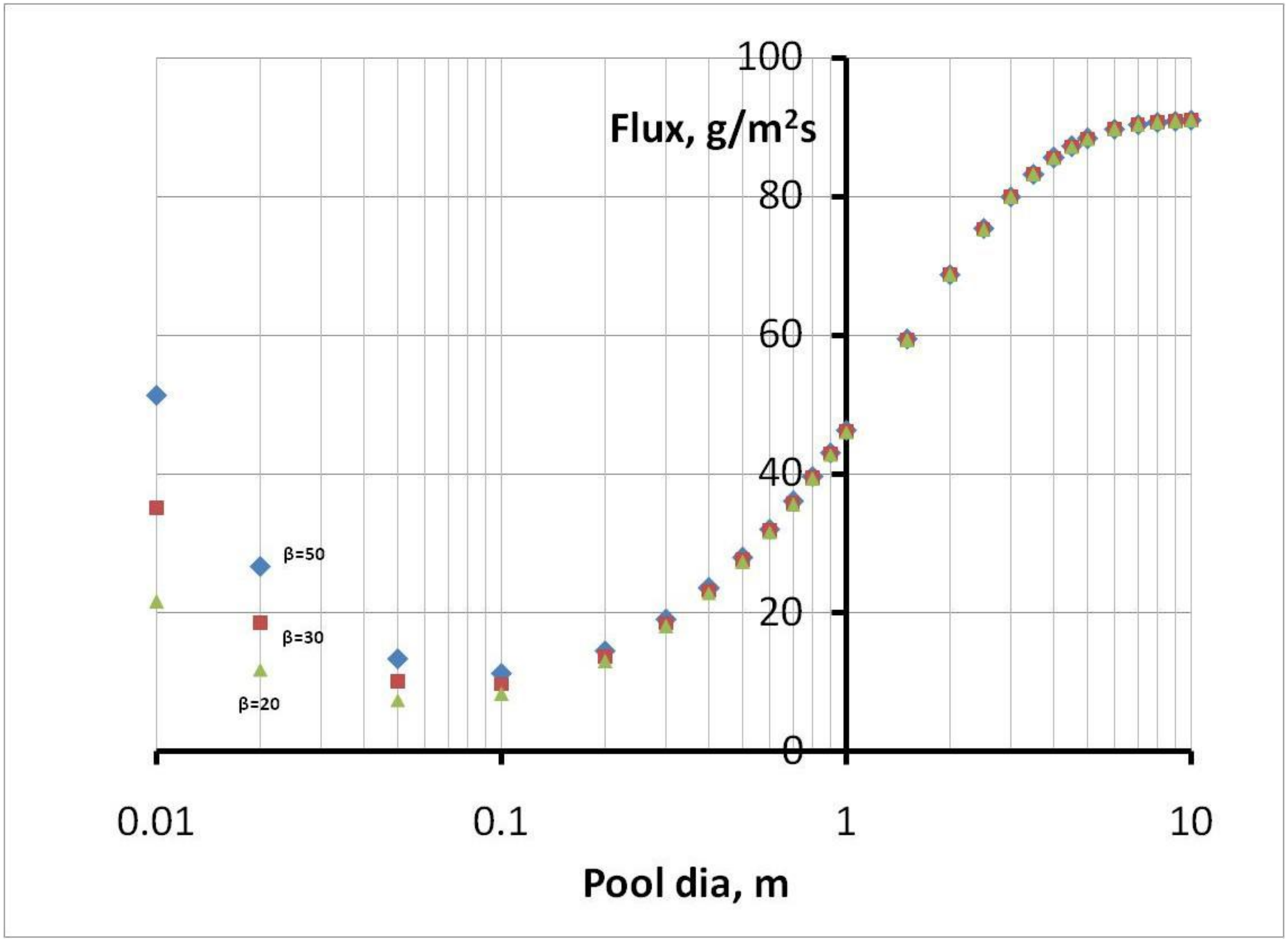
$$= \frac{\dot{q}''}{H_s} + B\frac{4t_w}{d_p}\frac{k_w}{c_{pg} l_{tf}}\frac{1}{1+\beta} \ln\left(1 + \frac{l_{tf}}{l_{t,ini}}\right)$$

$$\beta = \left(\frac{k_w}{k_g}\frac{\delta_g}{l_t}\right)$$

Thus, if

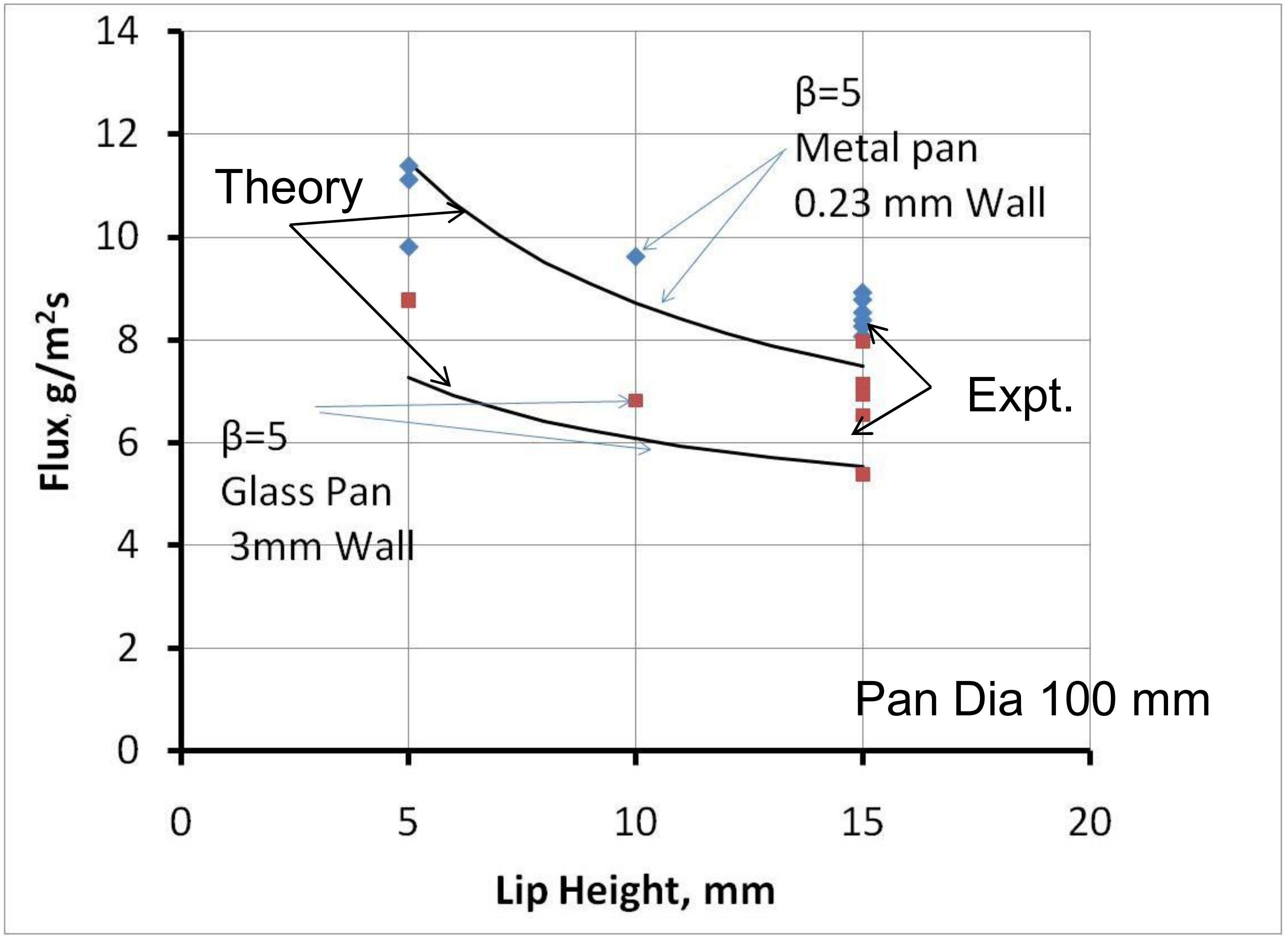
t_w is small	Cond. Corrections are small
K_w is small	Cond. Corrections are small
d_p is large	Cond. Corrections are small
β is Large	Cond. Corrections are small

Heptane Flux vs Dia. of Pan



It is seen that β is small on small burn rate

Lip Height Influence, Comparisons



Model is able to predict lip height influence on fuel flux

Conclusions

Experimental studies presented quantify the wall conduction effects in small pool fires.

In small pool fires wall conduction modifies the burn rate significantly

Free Board increase has resulted in decreased fuel flux

Experimental comparisons are drawn between a metal pan and glass pan
Free board T and mass histories are indicative of nearly const liquid
Surface T in metal pan beyond initial transients while glass pan has a
gradually increasing fuel surface T

Flux histories in glass and metal pans are indicative of similar values beyond initial transients

Visual techniques are employed with some success to obtain free board data

A modeling technique considering radiative & conductive power balance is presented

Thank You