7th Prof. P J Paul Memorial Combustion Researchers Meet

Pool Fires – clean fires and clean combustion

(Clean fires means fires with non sooty products
clean combustion means fires with complete heat release)

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Introduction

Pool fires being a part of standards for fire extinguishments, large pool fires are used in foam qualification test procedure.

These pool fires emit significant amount soot because the buoyancy driven reactive process in the core region occurs with very little oxygen.

Experimental studies were conducted to examine if pool fire can be converted to operate in clean combustion mode and to examine the changes in the mass burn rate and aspects of thermal behavior

Also experiments were conducted to examine if the pool fire can be made to operate leaving the near fuel surface processes unaltered, but burn away all the soot that accompanies it in the higher portions of the fire to ensure better environment compatibility in terms of exhaust.

Pans used for experiments

200 mm dia, 40 mm depth , MS Pan

1 m long x 0.2 m wide x 0.06 m high rectangular, MS Pan

Experiments

Initial experiments are performed in 200 mm diameter, 40 mm deep MS pan for n-heptane fuel thickness of 10 mm with and without external air supply

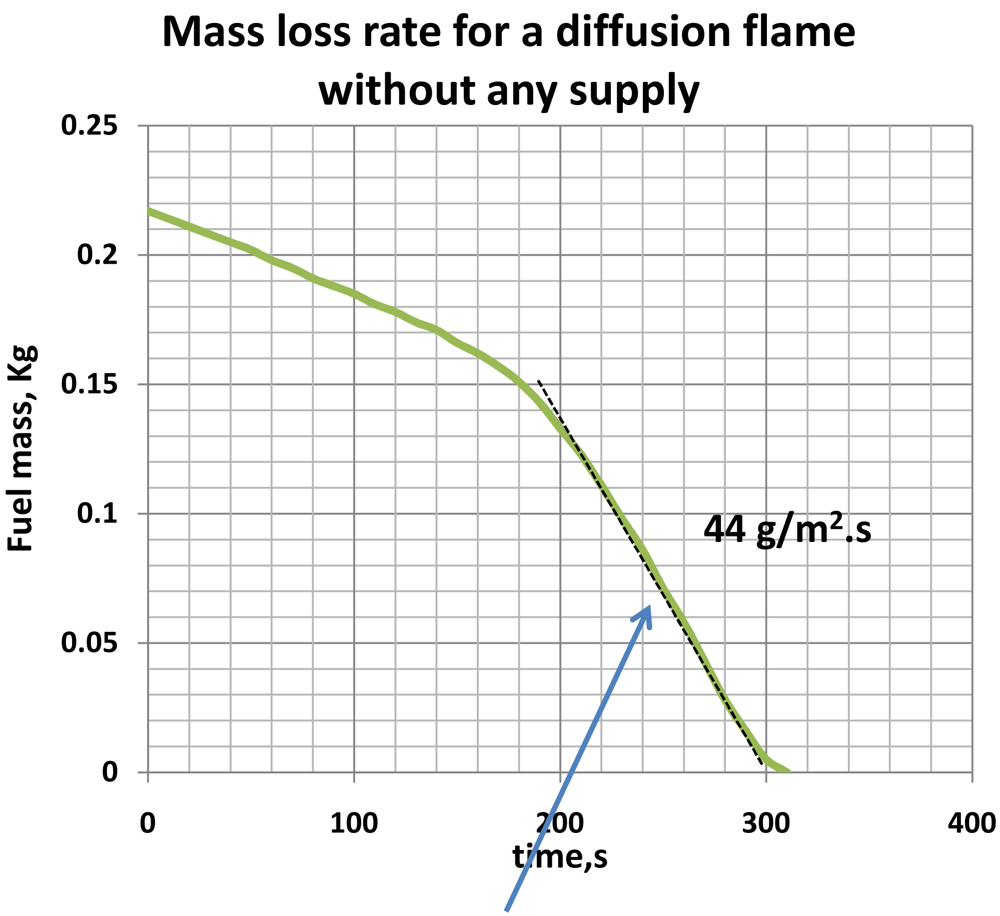
To supply air for circular pan, a ring type ejector system is used and air is supplied in axial direction by mounting the ejector at different heights (at 0.4 D, 0.3 D and 0.2 D).

In few experiments apart from the air in axial direction, a small amount of air (0.2 g/s) is supplied in the radial direction in the continuous zone to aid proper mixing of vapor with air in the zone immediately above the fuel surface.

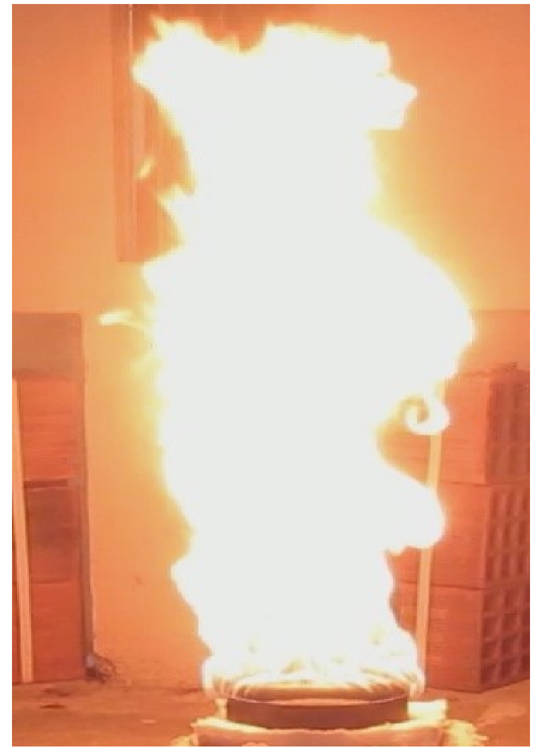
Data on mass loss rate, center line gas phase temperatures were obtained for the experiments.

Some intriguing aspects of burn behaviour is explored through analysis of data

Mass loss rate of 200 mm diameter, MS pan for 10 mm n- heptane without air supply

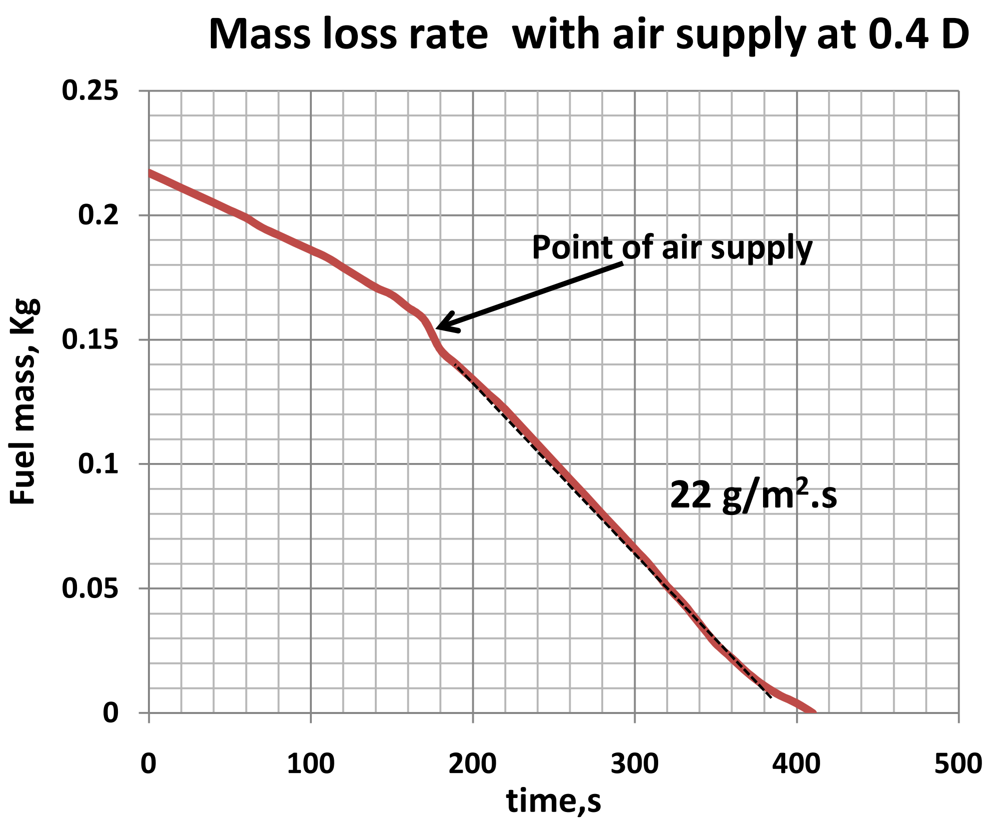


Flame structure during peak phase



- A peak flux of 44 g/m^2.s is due to increase wall conduction heat transfer rate in the pool fire which burns only by air entrainment without any external air supply.
- The unsteady flame which anchors to pan tip heats up the sidewall of the pan directly, increasing the wall conduction heat transfer to fuel.

Mass loss rate of 200 mm diameter, MS pan for 10 mm n-heptane with air supply at 0.4 D

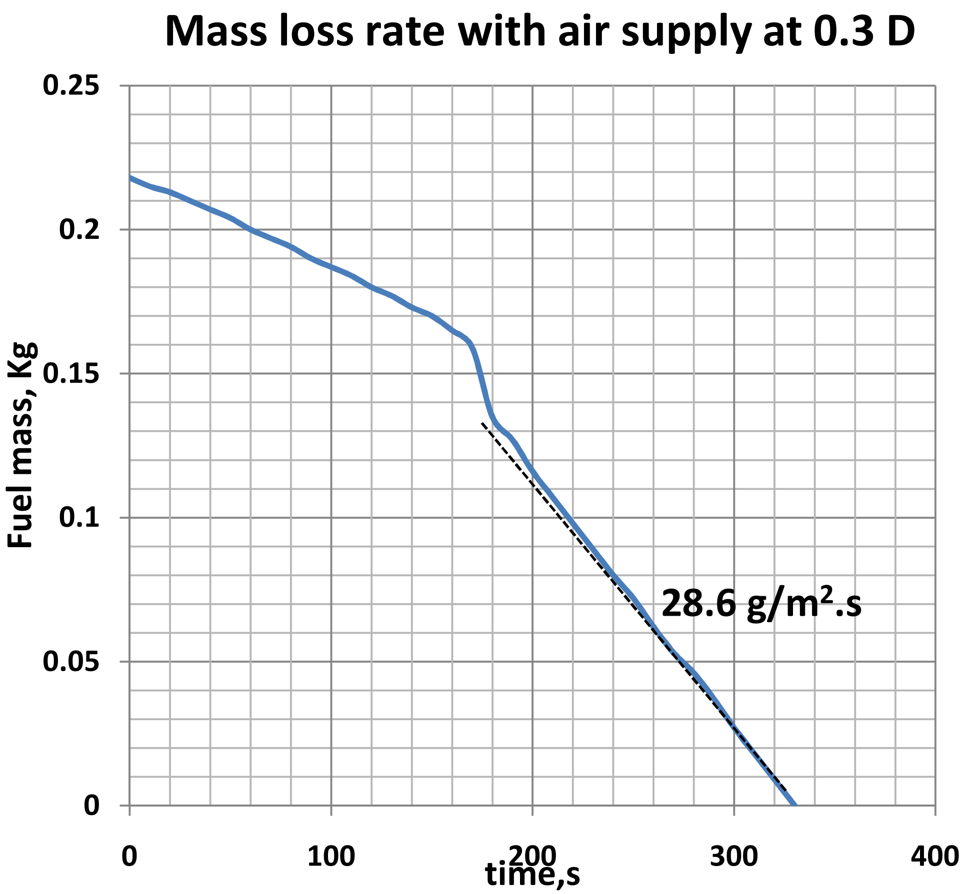


Flame structure during peak phase

Flame not anchored to pan tip

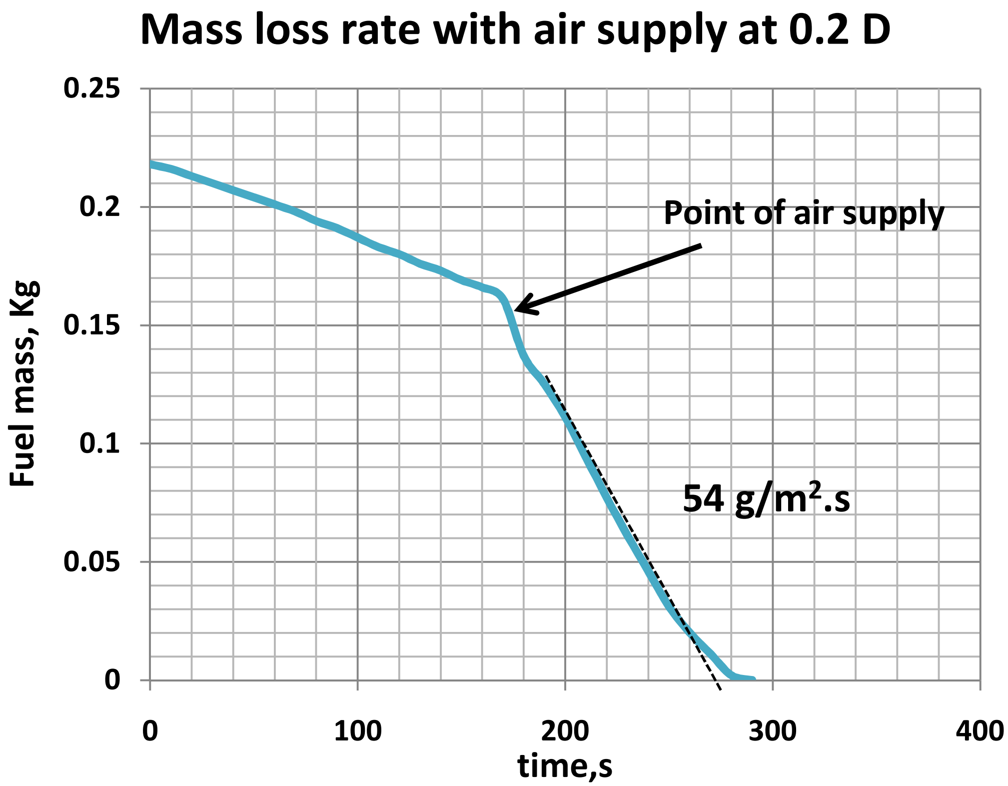
- With air supply at height of 0.4 D at a rate 8 g/s, the peak flux is reduced to 22 $g/m^2.s$ and the flame height reduces significantly.
- From the video examination, it was seen that flame was not anchored to the pan edge. This is inferred as reducing the conduction heat transfer rate and so reduced peak flux

Mass loss rate of 200 mm diameter, MS pan for 10 mm n-heptane with air supply at 0.3 D



With reducing the air supply height from 0.4 D to 0.3 D, burn rate increased to 29 g/m^2s. Better convective and radiative heat transfer may be responsible.

Mass loss rate of 200 mm diameter, MS pan for 10 mm n-heptane with air supply at 0.2 D



Flame structure during peak phase

- With air supply at 0.2 D (both axially and radially) at rate of 8.2 g/s, the peak flux has increased to 54 $g/m^2.s$, which is more than the peak flux obtained without air supply.
- The radial air is supplied at rate of 0.2 g/s which aids in proper mixing of vapor in continuous zone.
- Clean combustion of fuel vapors increases the flame temperature from 1200 K to 1350 K.

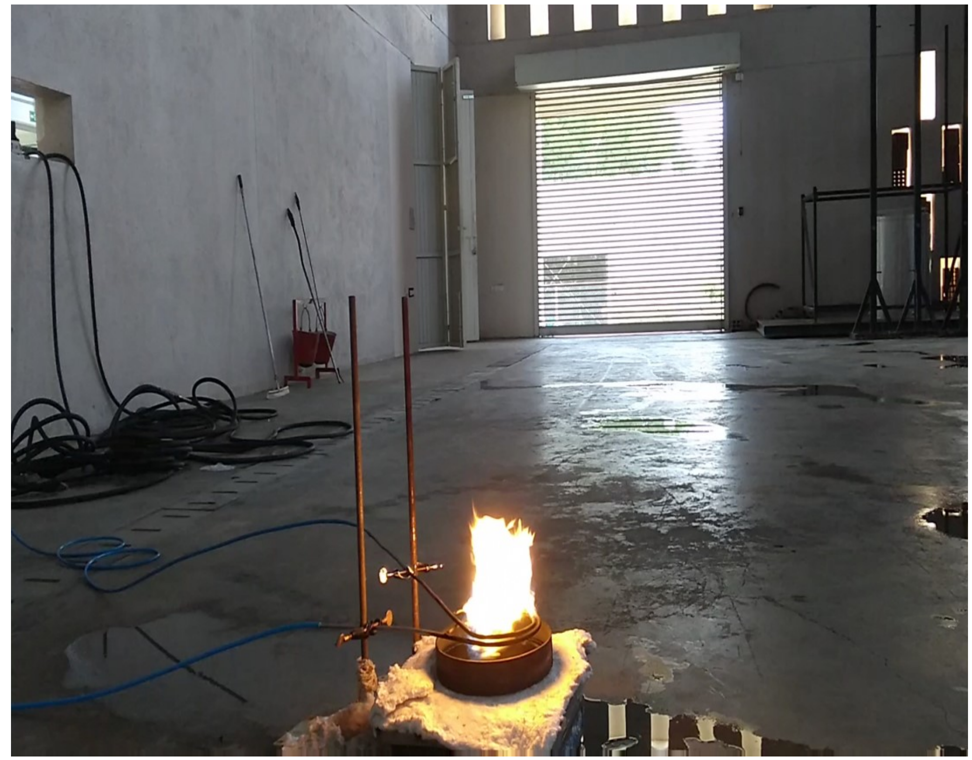
Flame behaviour of 200 mm diameter, MS pan for 10 mm n- heptane with and without air supply

Diffusion flame without external air supply

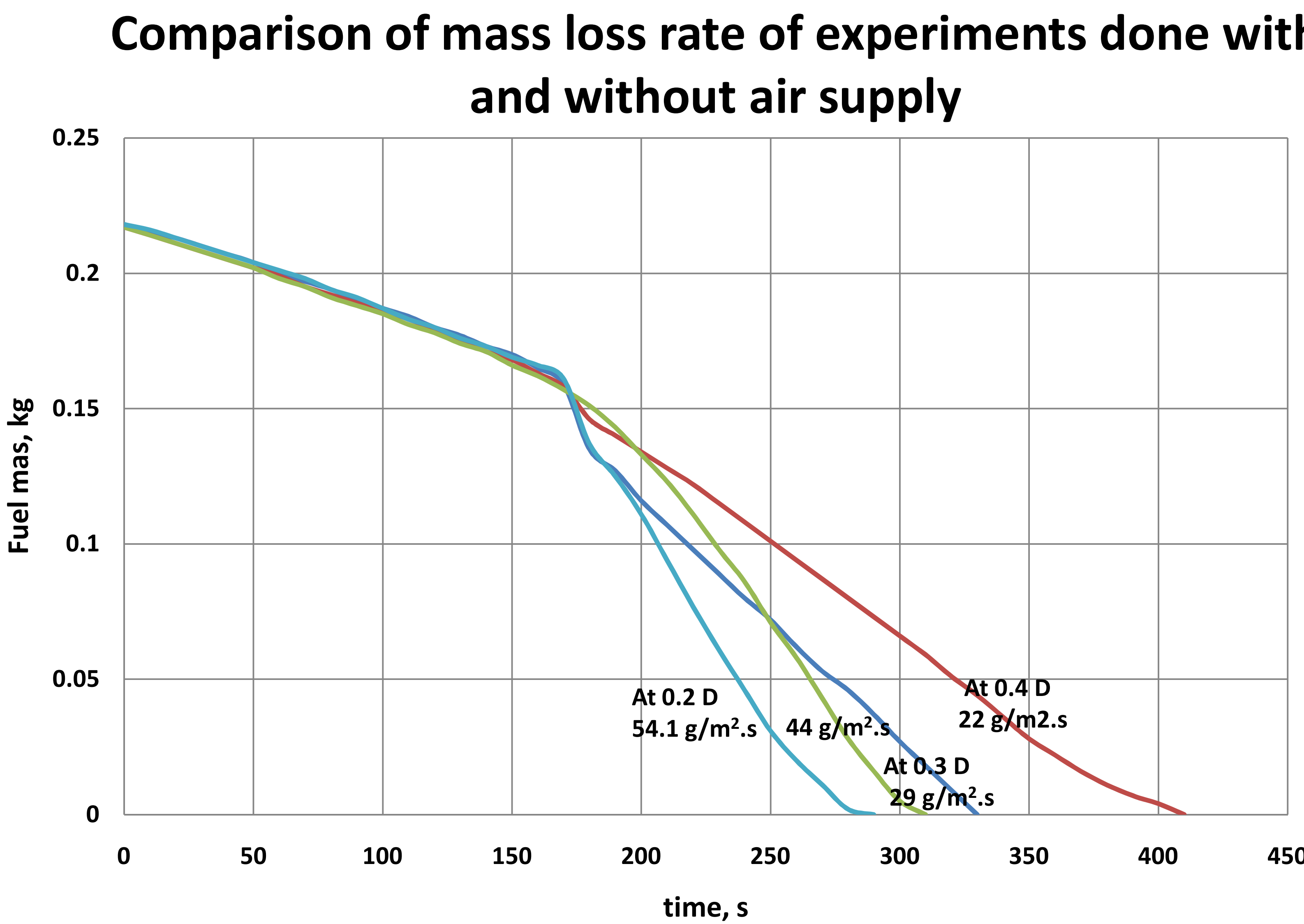
Air supply at height of 0.4 D

Flame behaviour of 200 mm diameter, MS pan for 10 mm n- heptane with and without air supply

Air supply at height of 0.3 D

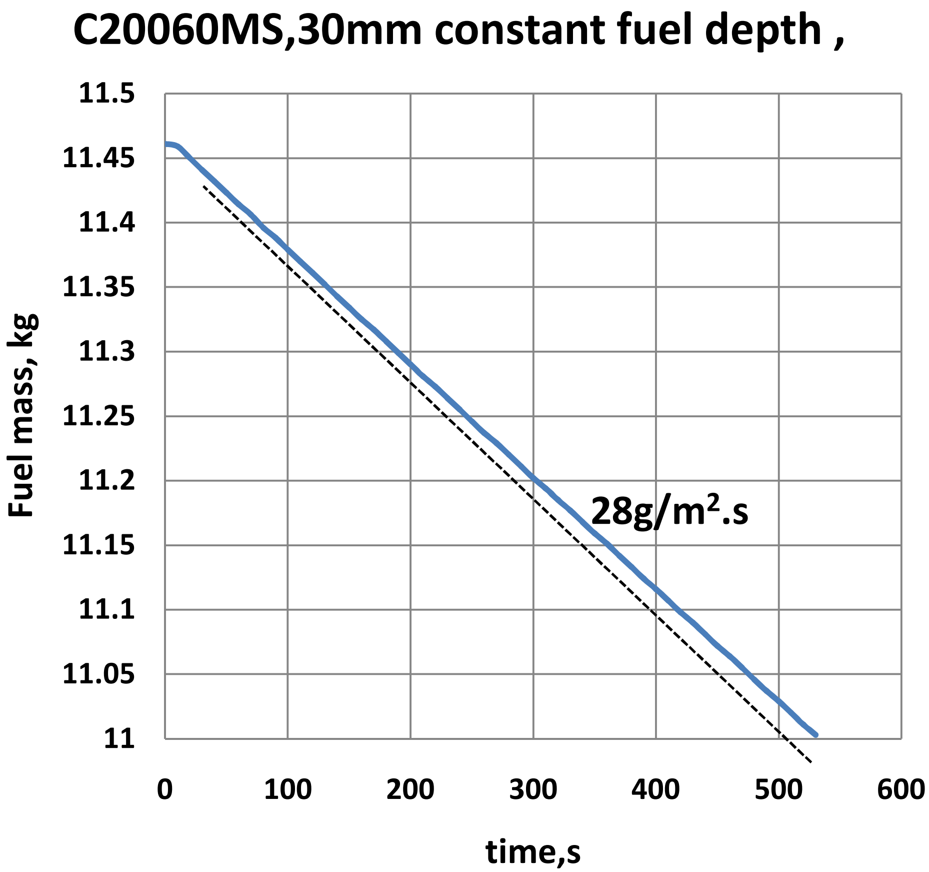


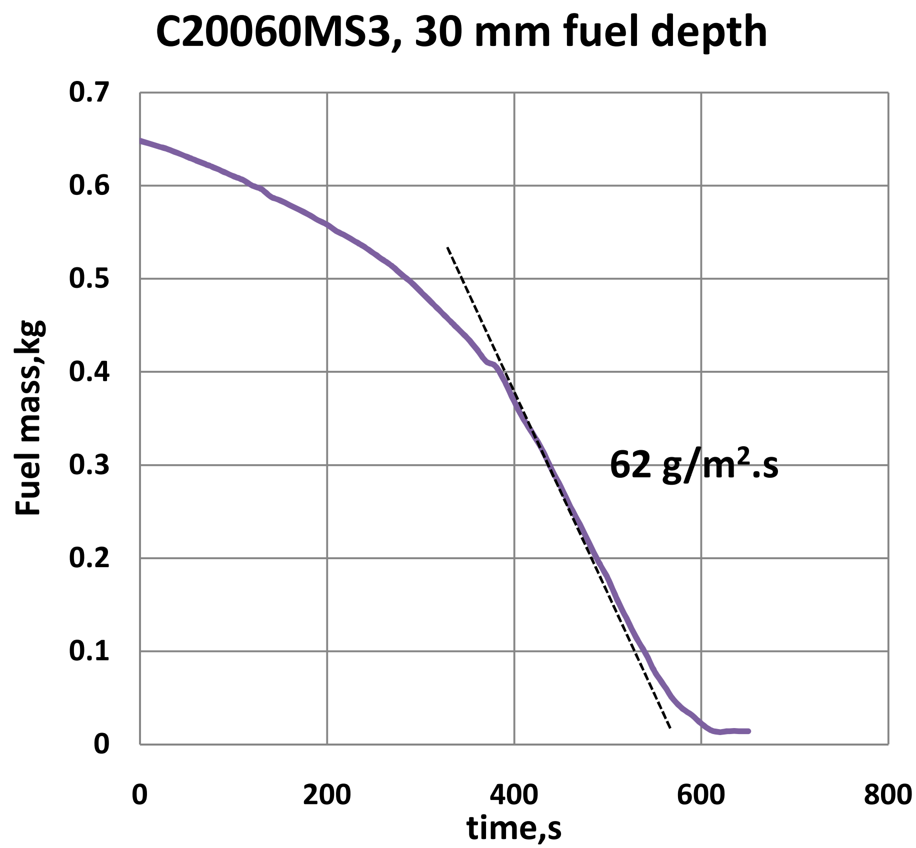
Air supply (both axial and radial) at height of 0.2 D



Supply of air at different heights affects the burn rate significantly which is evident from the mass loss curves shown.

Mass loss rate comparison of experiments in 200 mm dia, 60 mm depth MS pan with a constant and time varying fuel level



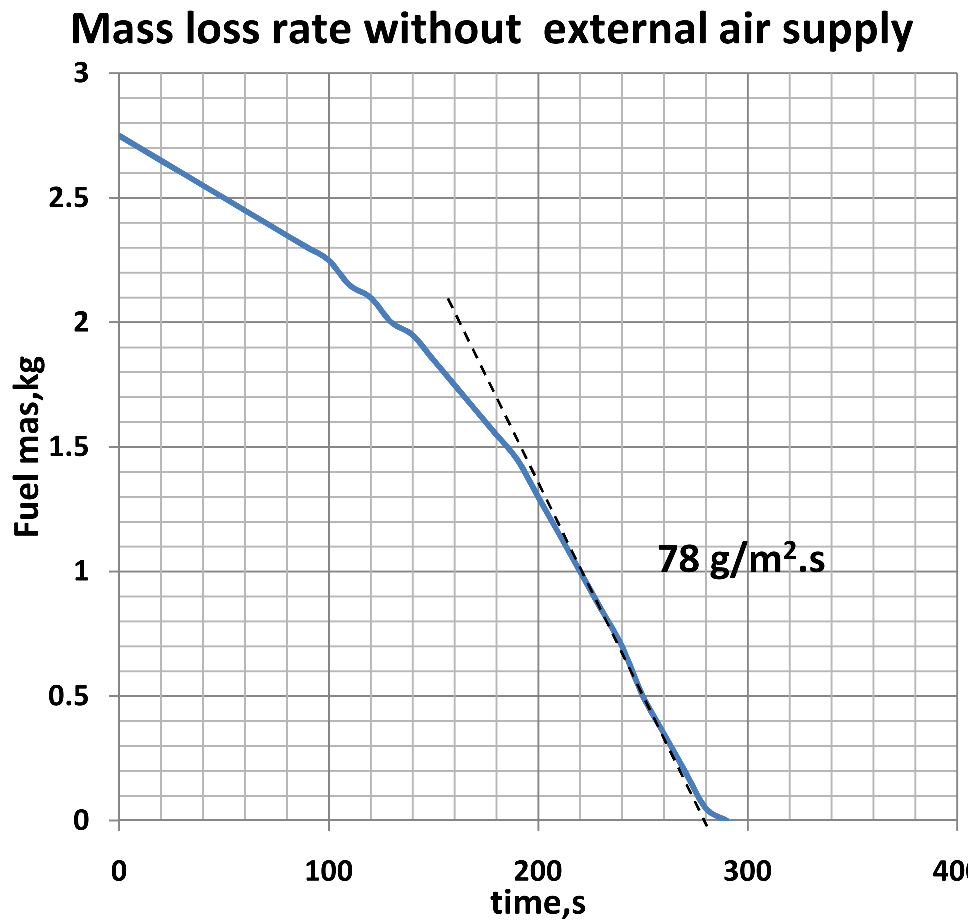


If a constant fuel level is maintained by continuous feeding of fuel into pan, then the bulk boiling phase will not reached and the flux remains constant throughout the experiment

Whereas with time varying fuel level experiments the bulk boiling of complete pool is reached due to increased wall conduction heat transfer which leads to higher burn rates.

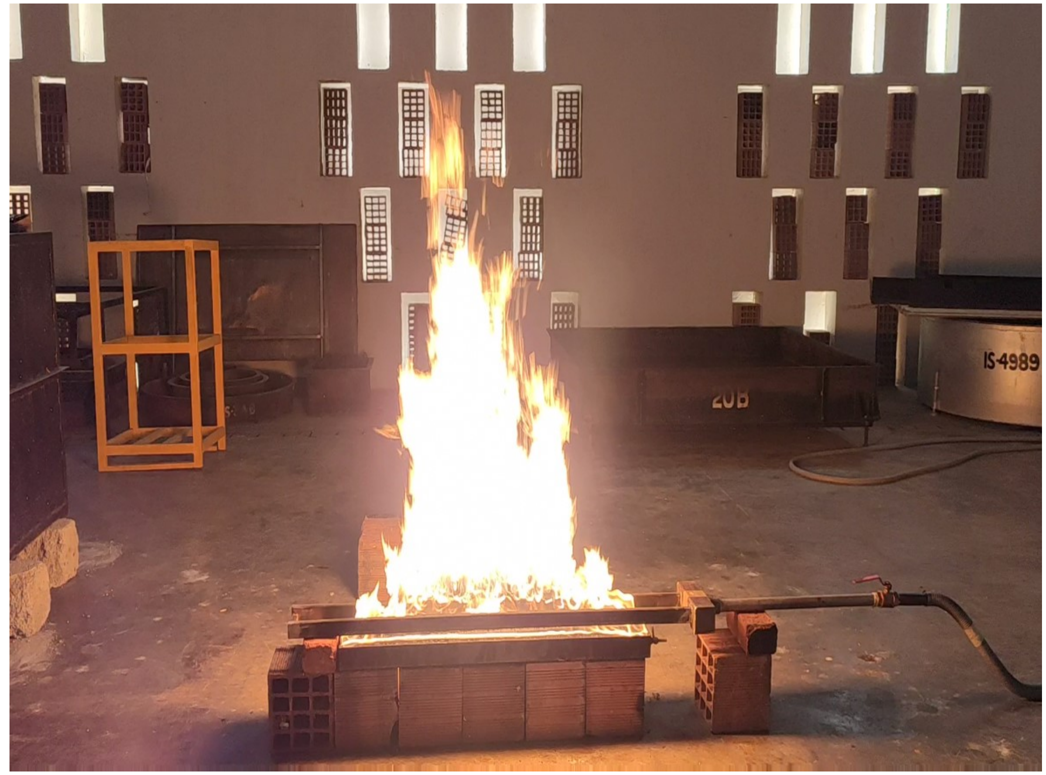
Mass loss rate of 1 m rectangular pan with 20 mm n- heptane

Flame structure during peak phase



In 1 m pan a peak flux of 78g/m^2·s for fuel depth of 20 mm n-heptane is obtained. Further experiments are carried out to obtain clean combustion of pool fires, so that it could be used as burner in real time applications.

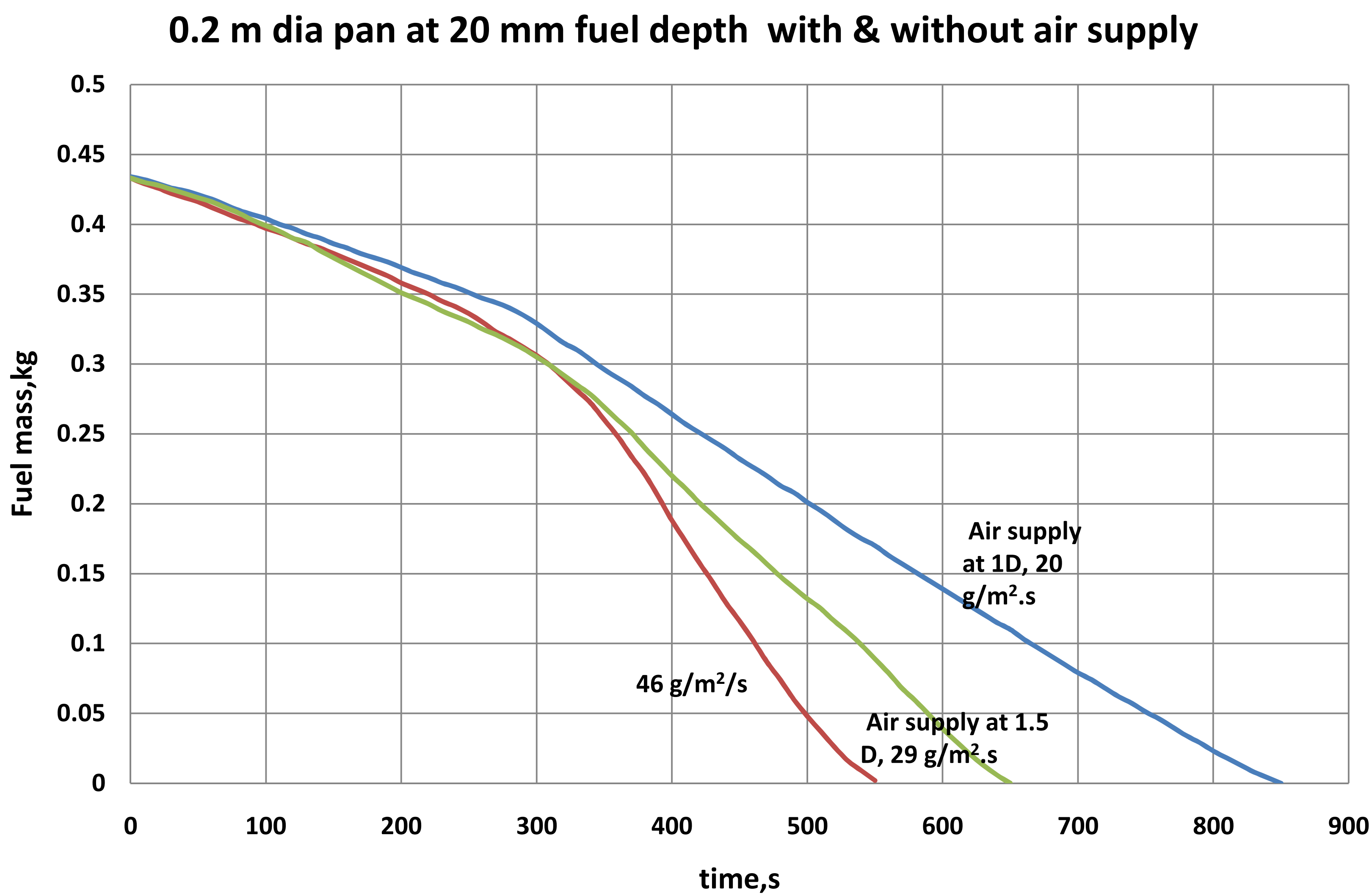
Flame behaviour of 1 m rectangular, MS pan for 20 mm n- heptane with and without air supply



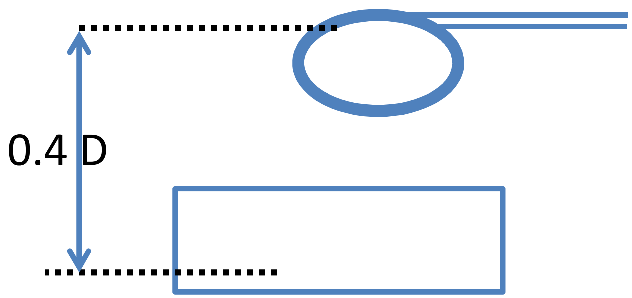
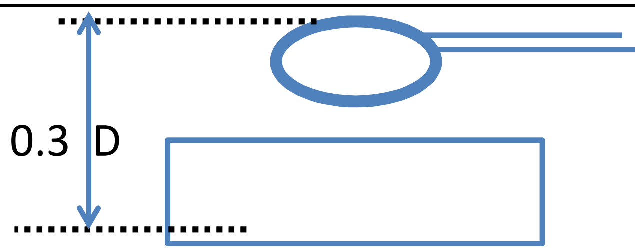
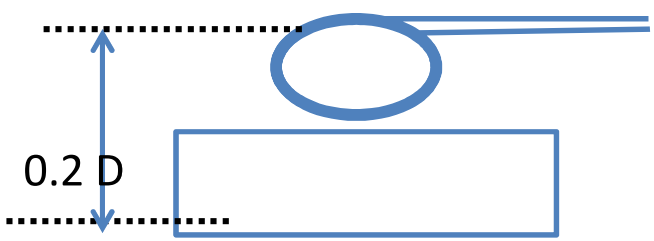
Diffusion flame without external air supply

With air supply at a rate of 46g/s

Experiments to obtain clean fires



With air supply at 1 D and 1.5 D the flux reduces as shown in plot , further experiments are to be done to only reduce the soot without affecting the burn rate.

SL. NO	Configuration (Air supply height from fuel surface)	Peak flux in $g/m^2.s$	Remarks
1	External air not supplied 	44	Peak flux is due to increased heat transfer rate
2		22	Reduction in the peak flux is due to decreased wall conduction heat transfer rate
3		29	Flux increases slightly.
4		54	Increased flux is due to proper mixing of fuel air mixture in continuous zone

Conclusions

Burn rate in the pool fires with air supply strongly depend on the height at which the air is supplied, by varying the height a required burn rate can be obtained with much clean combustion compared to pan fire that burns on its own by air entrainment.

In the small diameter pans with air supply, flame structure is altered drastically, affecting the wall conduction heat transfer to fuel which in turn affects the burn behavior

From these experiments it is evident that a clean combustion pool fires can be obtained to use them in real time applications (example as a burner in 1 m^3 fire resistant test furnace)

The experiments will be extended to 2.1 x 2.1 m indoor pool fire to reduce the soot without altering the burn behavior at fuel surface…………….. thank you