JAIN DEEMED-TO-BE UNIVERSITY | FIRE & COMBUSTION RESEARCH CENTER

DEFENCE RESEARCH AND DEVELOPMENT ORGANISATION

6TH Prof. P. J. PAUL MEMORIAL
COMBUSTION RESEARCHERS' MEET
and Workshop on Combustion Science in Biomass Fire and Instability- Science in the Aid of Practice

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Studies on Nano-Boron Powder Combustion in a Liquid Fuel Combustor (for gas turbine) at Ambient Pressure

CS Bhaskar Dixit, G Prasanna Desouza, Y Srinath, HS Mukunda

Background

- Boron with its 30% higher energy content >250% higher density compared to conventional HC fuels increases energy density of air-breathing propulsion systems significantly

- Issues that need resolution are:
- Indigenous production of nano-boron at optimized costs
- combustion when integrated in a slurry form with high density liquid fuels like JP-10 or directly or as powder.

- Boron requires high ignition temperatures (> 1600 °C) & current approach aims to introduce an air-jet induced Nano boron directly into the high temperature zone of the combustor.

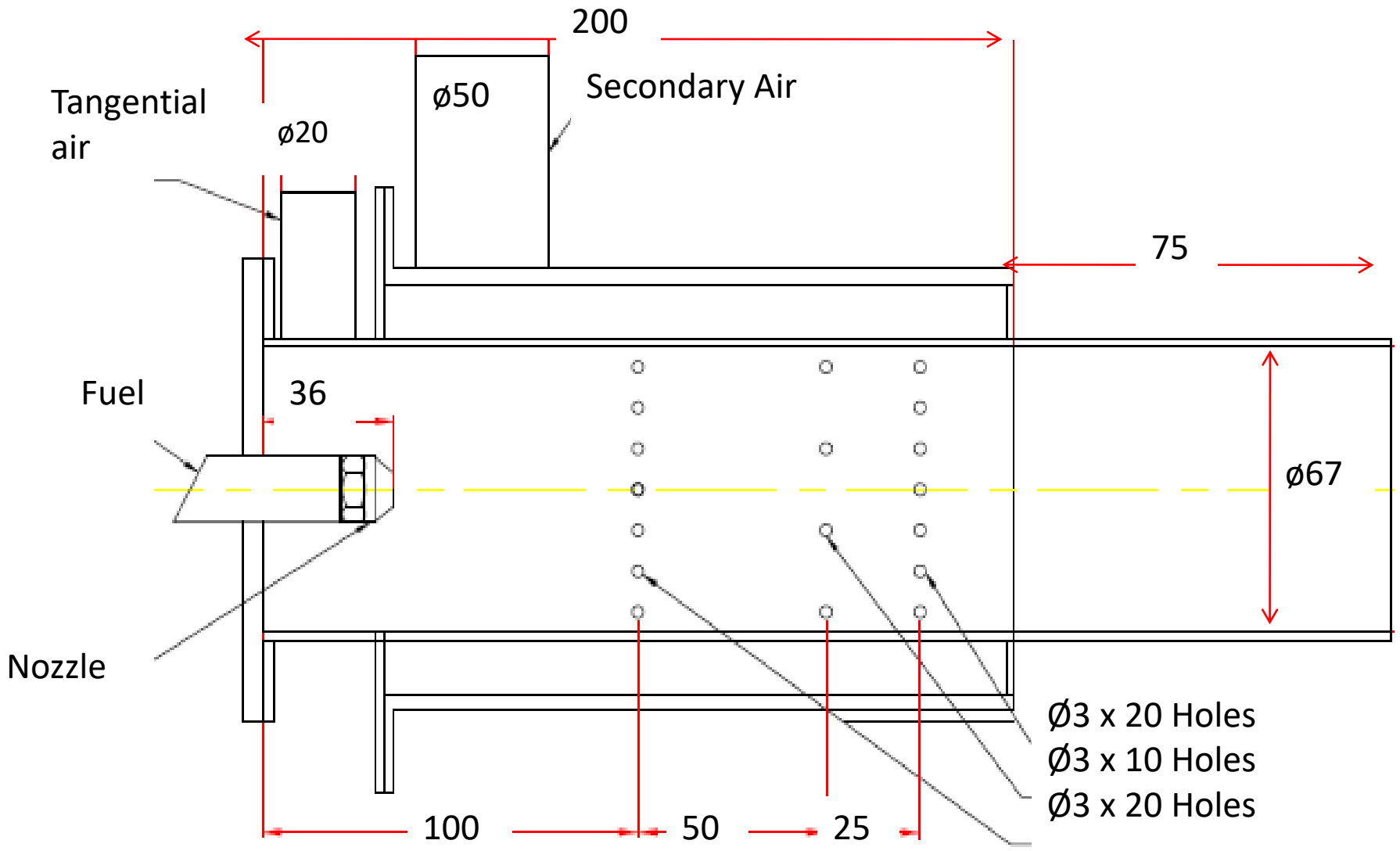
FCRC Developments

- At FCRC, a work was initiated in 2013-14 to evaluate the feasibility of powdery boron combustion
- Boron powder (costing ~ Rs 600/g in open market) was synthesized from boric acid through magnesio-thermal reduction and was combusted in a standard LPG T-20 burner (30 kW) successfully
- Results were presented in 2016 GATET workshop at GTRE
- Subsequently, CARS project was given by GTRE in 2018 to FCRC for Boron synthesis and combustion in a liquid fuel combustor at ambient pressure
- In an accompanying presentation, the production of high purity nano-boron was described by Dr. Sowriraajan

Preliminary Combustor Trials

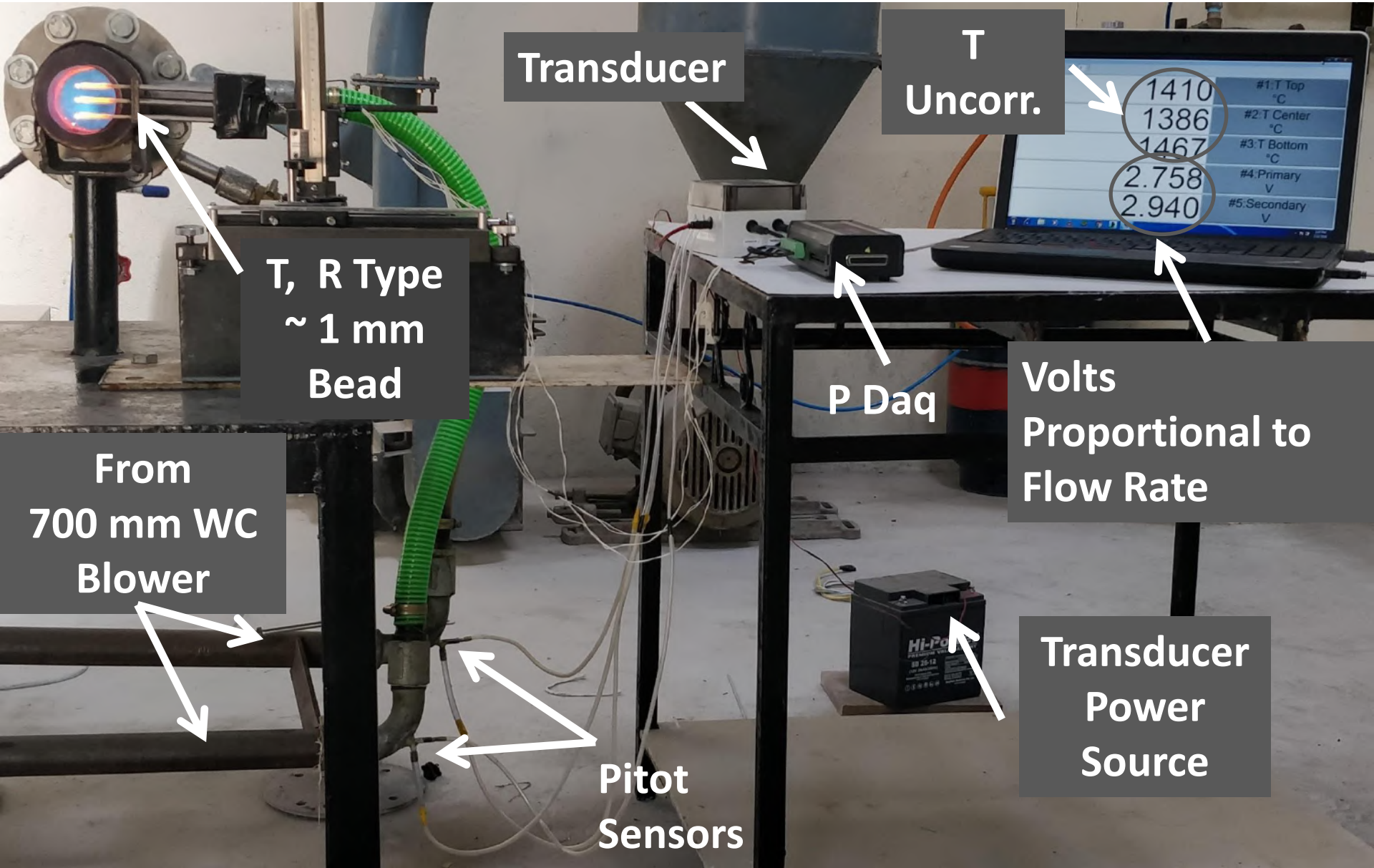
- Preliminary combustion trials have shown that a steady and stable flame is obtained between an air-to-fuel ratio (A/F) of 25 to 50
- Thermocouple measurements of flame temperature with R-type thermocouple of 200 µm bead diameter show values of 1350 to 1650 K for the range of A/F indicated
- The temperature variations across the combustion chamber correspond to a pattern factor [(max temp – min temp)/mean temp} of 0.15

Ambient Pressure Combustor Schematic



SS combustion chamber is 70 mm internal diameter with tangential air supply at the head end and through two rows of 2 mm dia holes, ten in each row on the periphery of the inner shell.

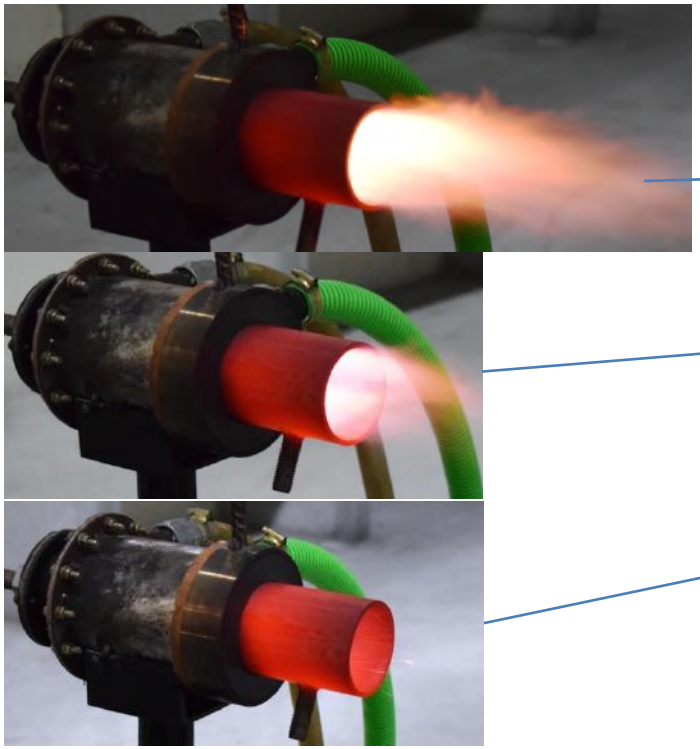
Combustor Test Setup

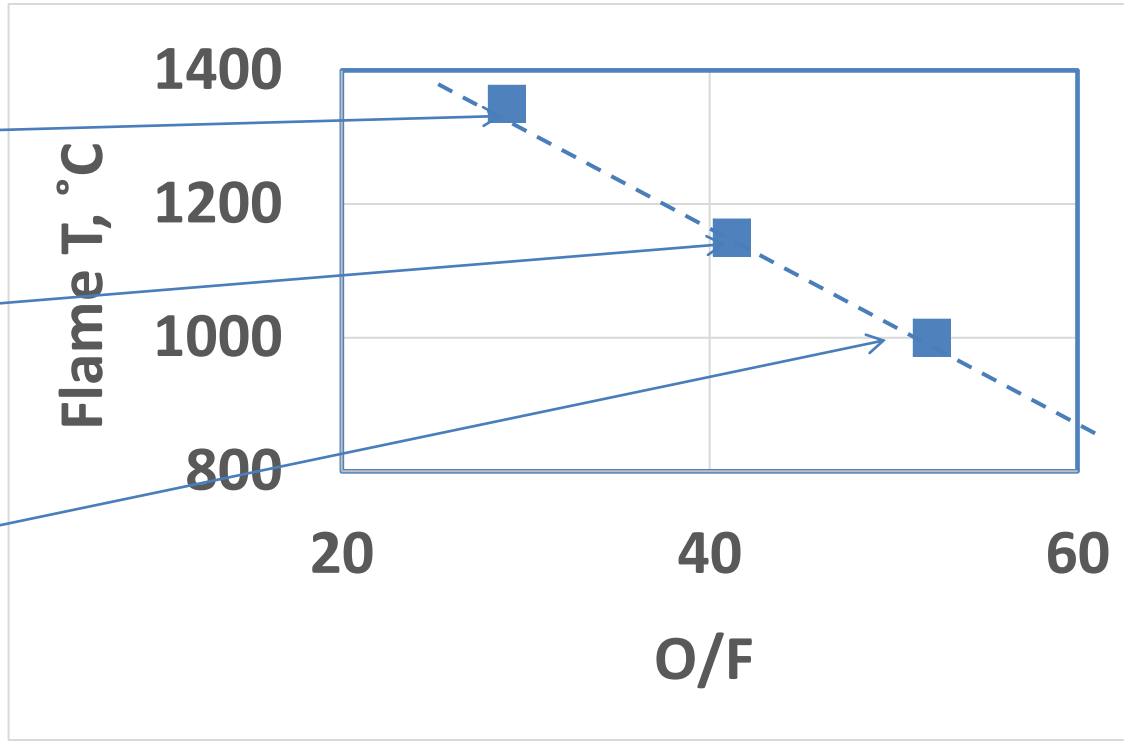


Initial Test Run

Kerosene Trials, 0.75 g/s

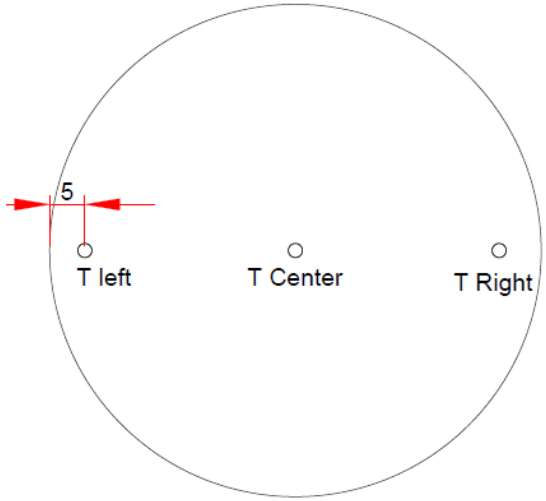
Combustor Exit T Data



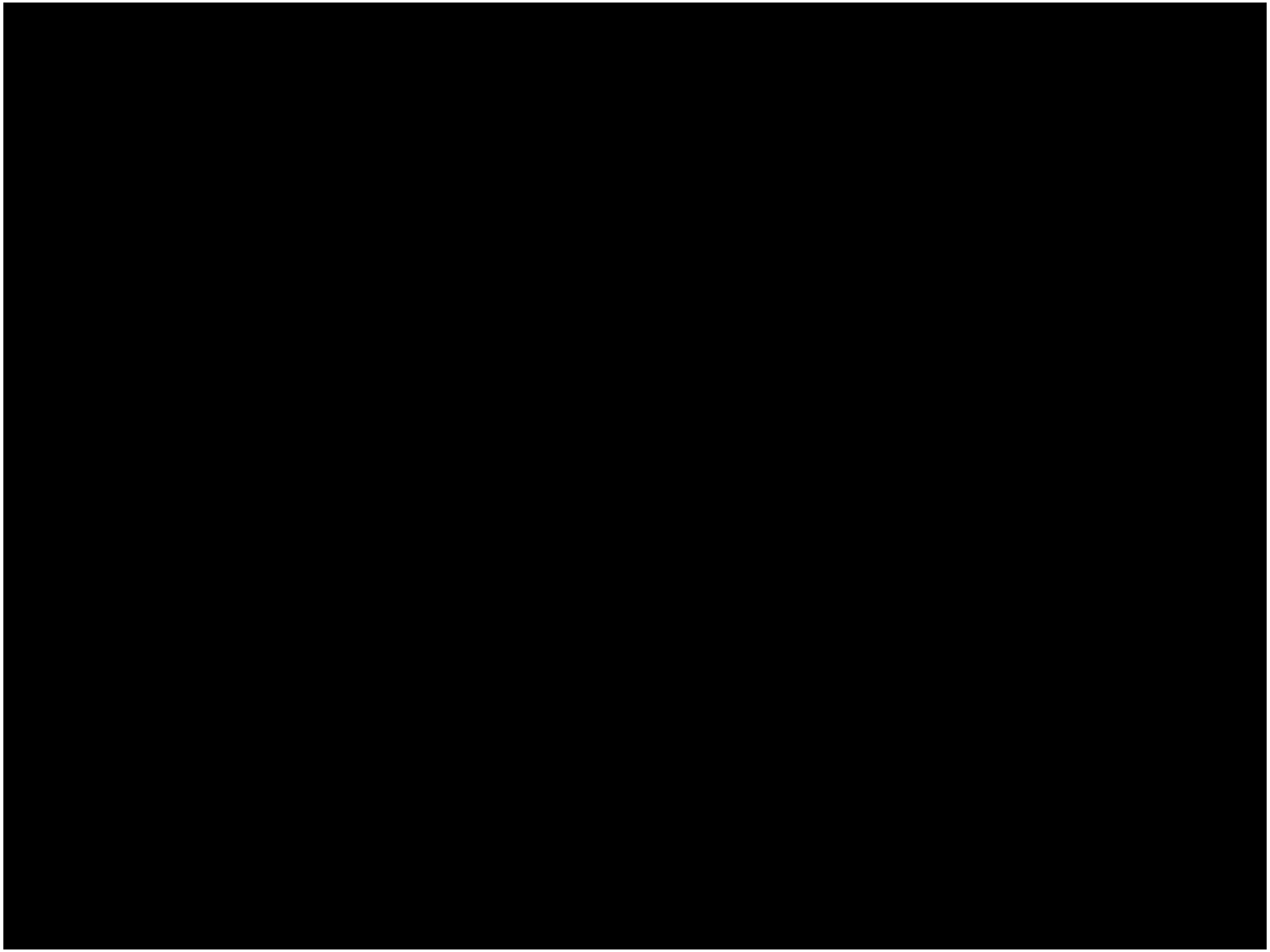


The T variations across the CC correspond to a pattern factor $[(T_{max}-T_{max})/T_{max}]$ of 0.15.

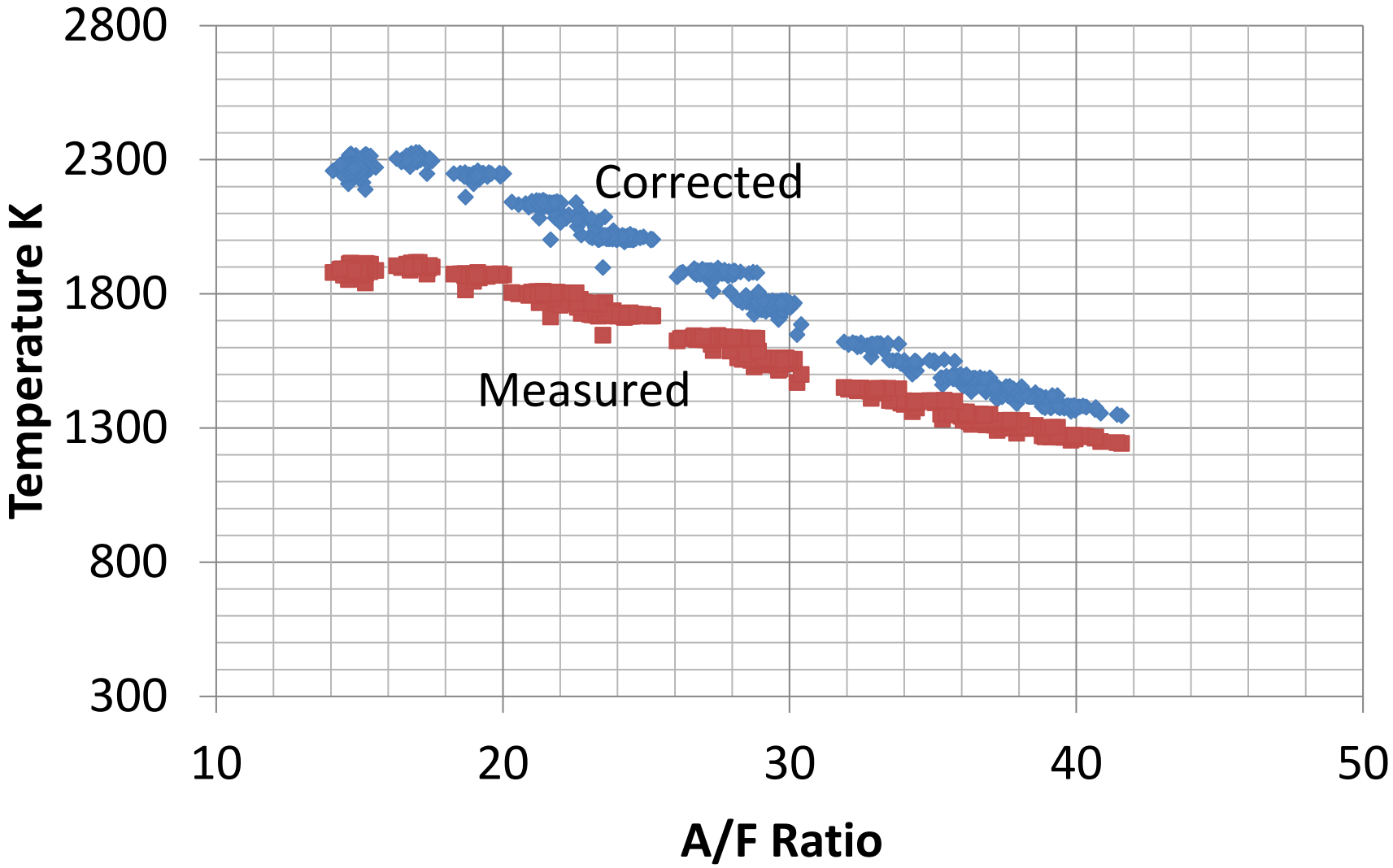
Mean g-Temp	Mean Air velocity	Mass flow rate	A/F	$\Delta T/T_{mean}$
°C	m/s	g/s		
1000	11.5	44.26	52.07	0.079
1150	9.1	35.02	41.20	0.070
1350	6.4	24.63	28.98	0.062



Combustor Trials

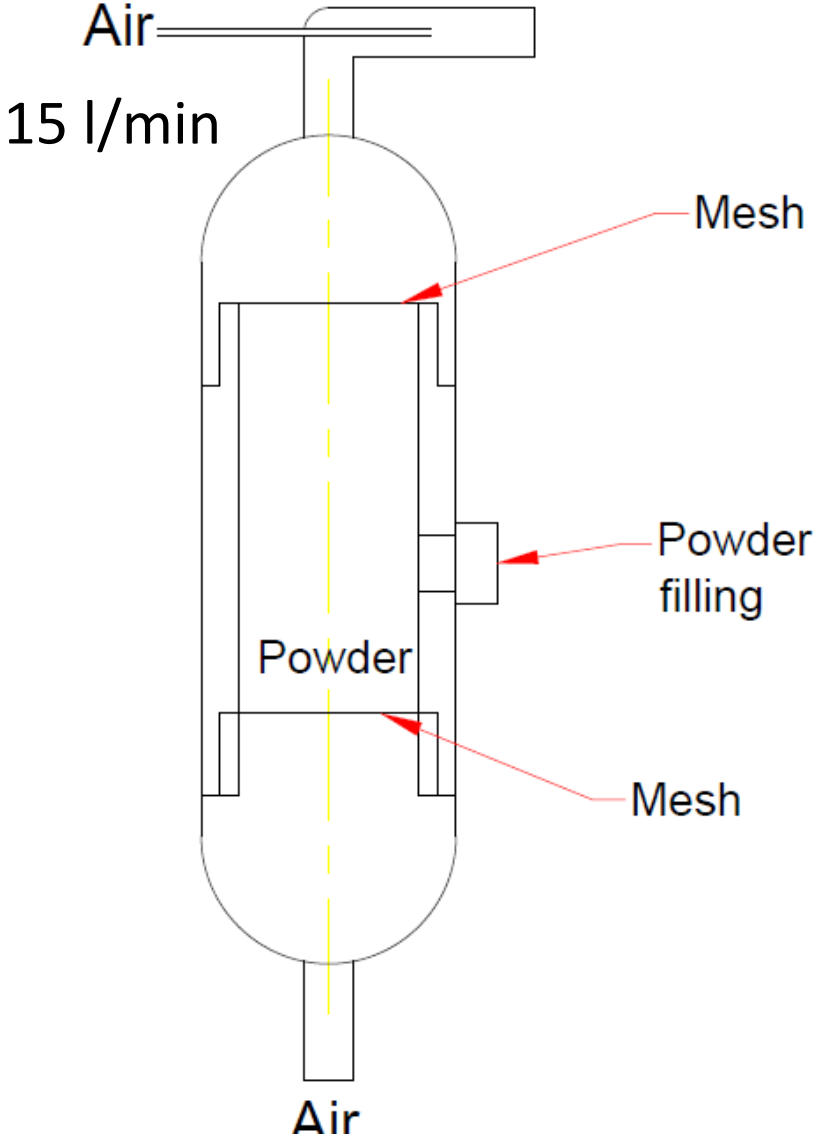


Combustor Trials: Exit T Profiles

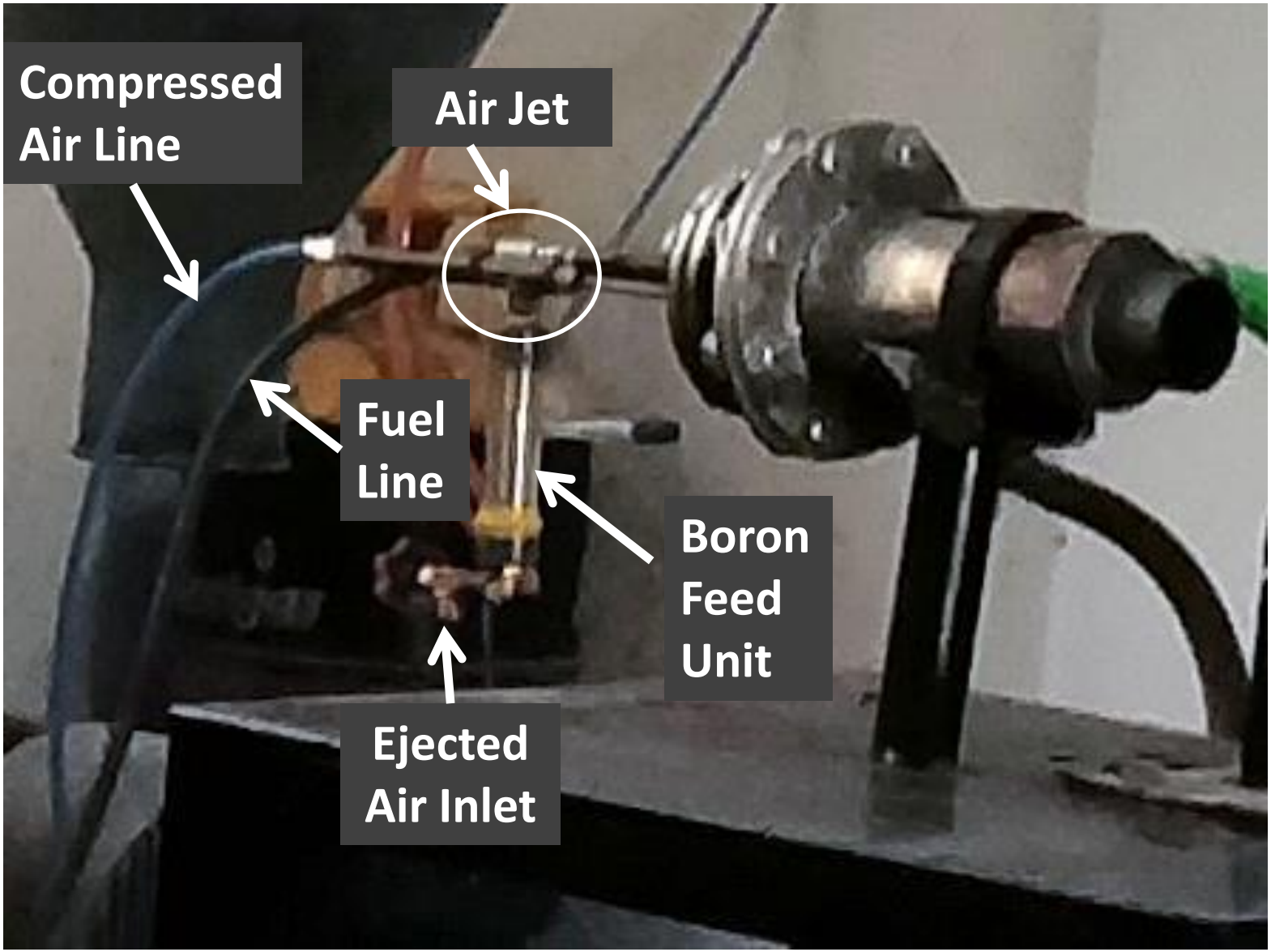


Boron Dispensation Unit Schematic

• Boron dispensation system for trials
will consist of a glass tube with curved ends
•A central port is provided for loading powder
•Air at 15 l/min issuing from a 1.8 mm dia nozzle (~100 m/s) entrains powder
Initial flow rate trials carried out using face powder

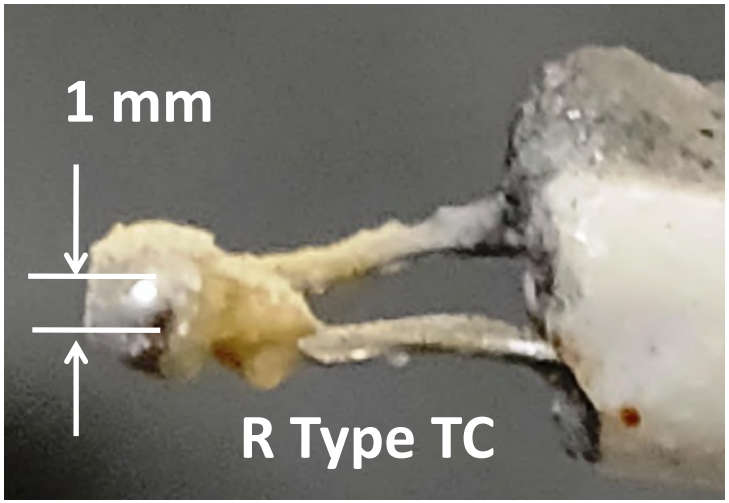


Boron Dispensation System



Combustor Trials with Boron Powder

- Fine boron powder injected into the combustion chamber with the peak temperature of ~1400 K at 5% of kerosene flow rate showed an increase of 200 K indicating that boron has enhanced the heat release inside the combustion chamber
- Boron flow stabilization and calibration is in progress
- B_2O_3 coating on TC observed



Work Plan

- Further experimental studies are in progress to establish exit temperature contours at the spectrum of A/F needed for combustor operations.

- The plan of experiments includes measurement of temperature contours at specific air-to-fuel ratios with kerosene and JP-10 fuels

- Comparison of the combustion process by direct injection as well as boron injected as slurry with both liquid fuels.

Thank You