Development of Porous Radiant Burners for Domestic LPG Cooking and Industrial Applications

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About IITG

- Located in the Gateway of North – Eastern Part of India
- Started 1995, established during 2005.
- Beautiful campus among other IITS. Located on the river bank on Brahmaputra[Yarlung Tsangpo-Siang-Brahmaputra-Jamuna]. Campus is surrounded by many Hills and Lakes.
- Campus size about 700 acr.
- 8 Engg and 4 Science Departments. About 6000 students, 425 faculty and 500 supporting staffs
- Few thousands of migratory birds, wild cats, etc.

The Campus

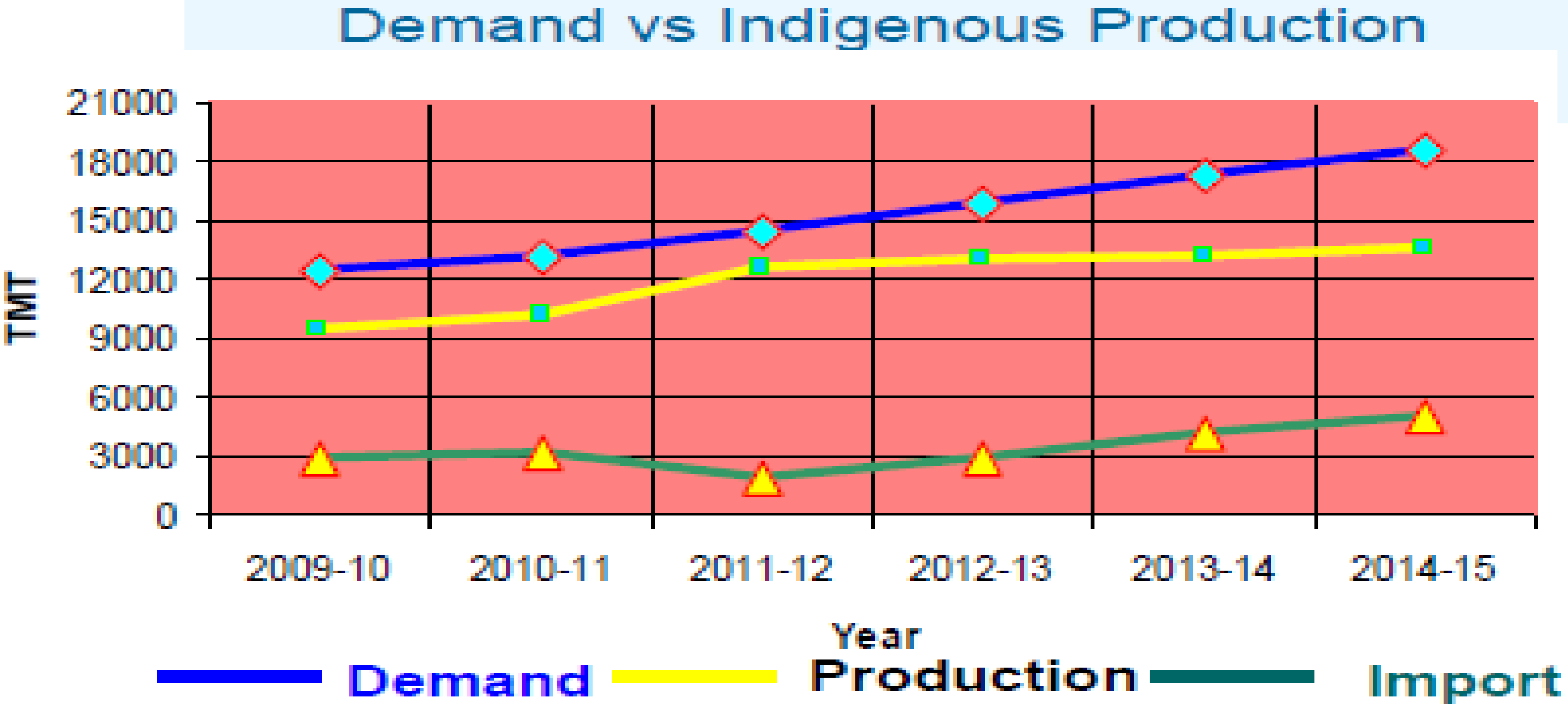


Out line of Presentation

- **Indian LPG consumption pattern**
- **Concept of porous medium combustion (PMC)**
- **Advantages of PMC**
- **Development of Porous Radiant Burner (PRB)**
- **Performance testing**
- **Concluding remarks**

- **India is the fourth largest consumer of LPG in the world**
- **India is not self-sufficient in LPG – has to import a huge amount of LPG.**

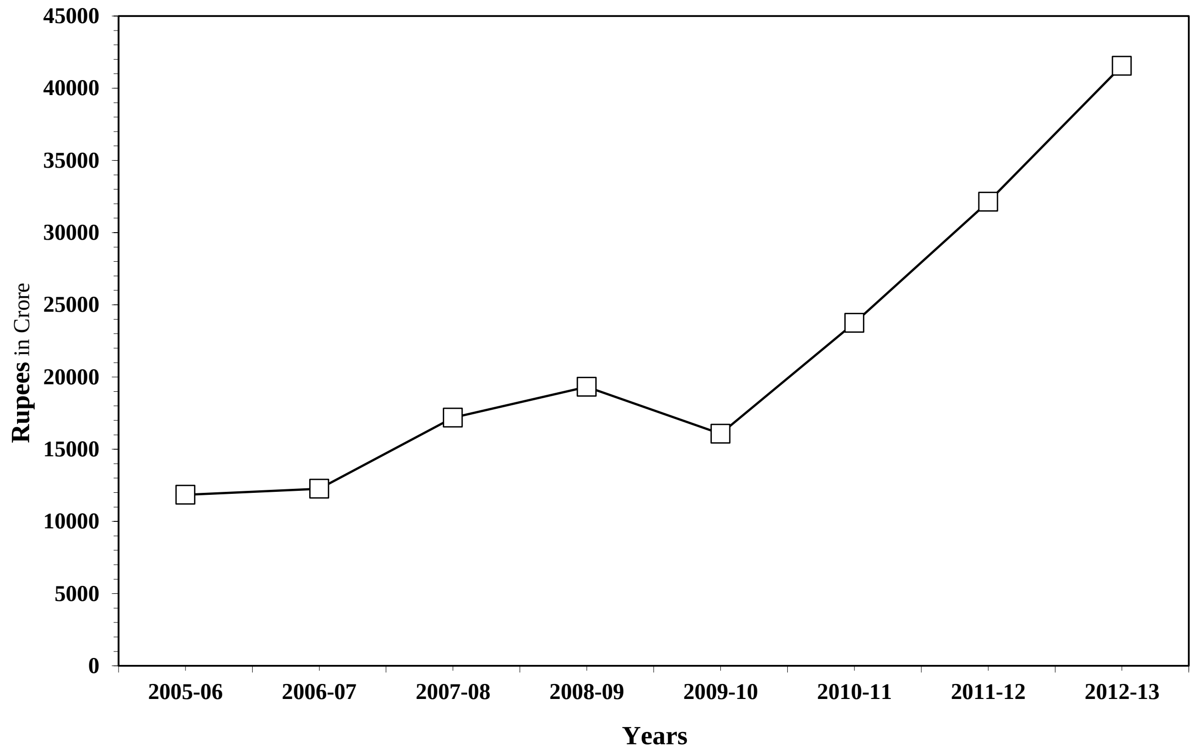
LPG: Propane – 57-60% + Butane – 40- 43%



India: ≈1.2 billion

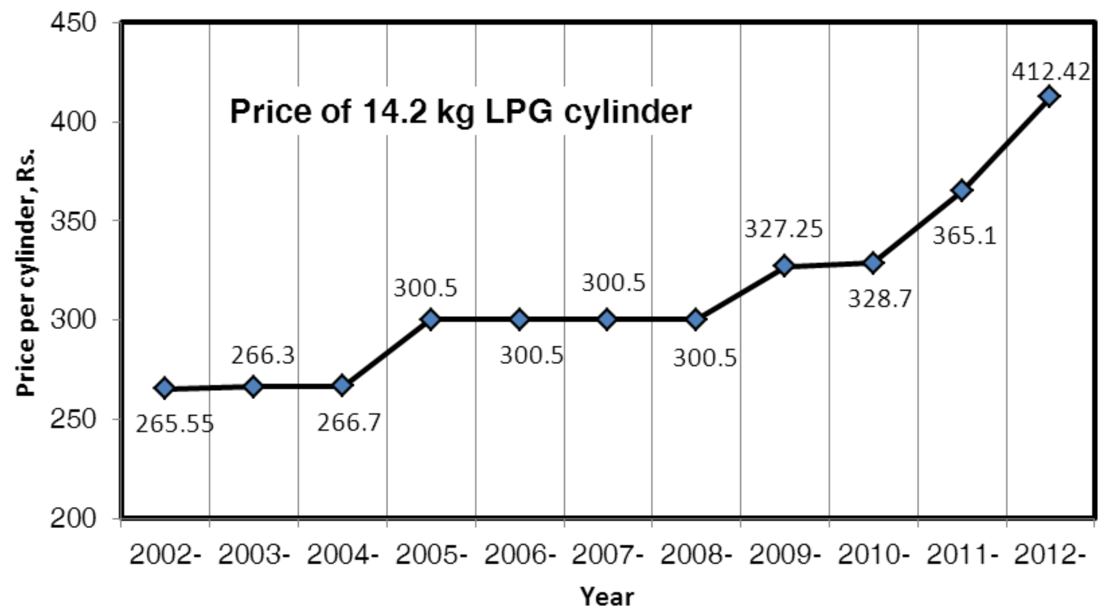
Number of LPG Consumers:246,692,667

Government provides a huge amount of subsidy ~ $7 Billion



For consumer too the price is increasing

From $16 to $ 6.8



Conventional LPG Cooking Stoves

						
Nikitsa Burner	Regular Burner	Side flame burner	Sunflame Burner	BPL burner	Super flame Burner	Aluminum base burner

Low thermal efficiency: 60 – 65%

High emissions

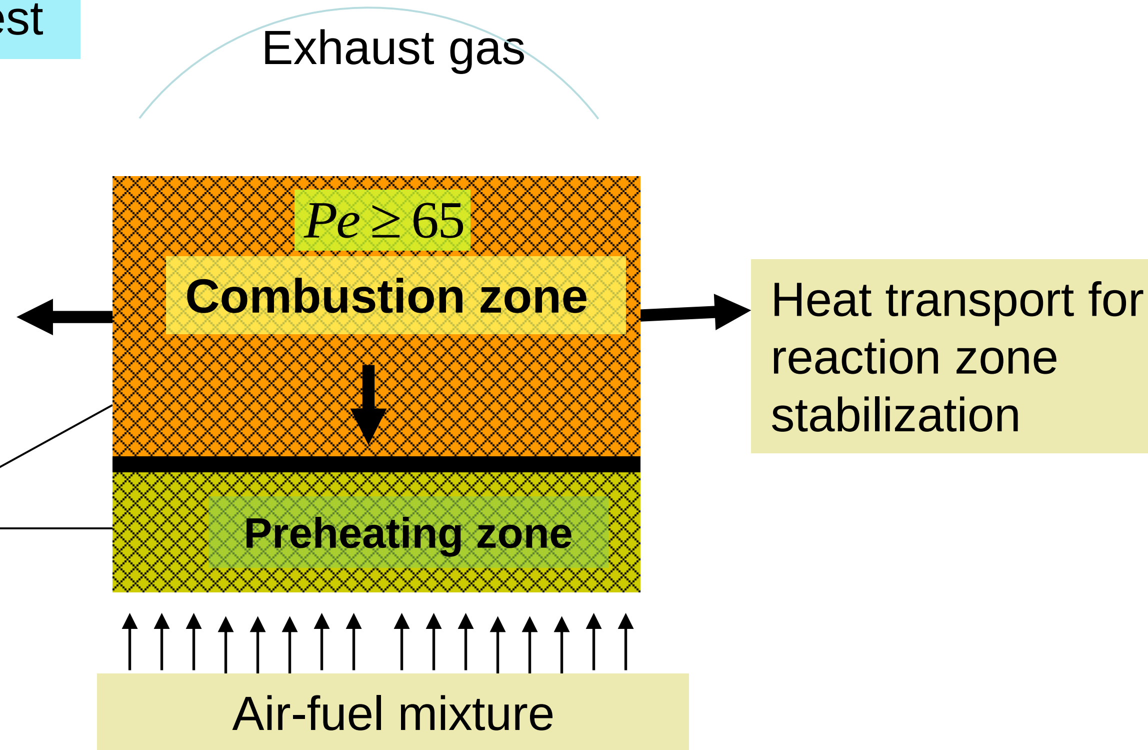
CO: 400 – 1050 mg/m^3

NOx: 160 – 220 mg/m^3

Conduction and radiation manifest

All three modes of heat transfer become important

Porous matrix



Flame propagation for:

$$\text{Pecklet number } P_e = \frac{u_L \rho c_p d_m}{k} \geq 65$$

where

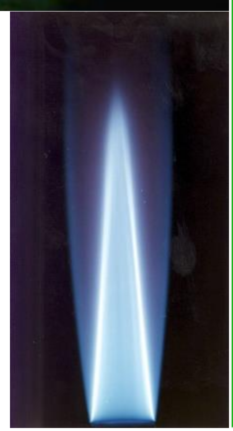
u_L	:	laminar flame velocity
d_m	:	equivalent porous cavity diameter
c_p	:	Heat capacity of gas mixture
ρ	:	Density of gas mixture
K	:	Thermal conductivity of gas mixture

Heat production

Heat removal

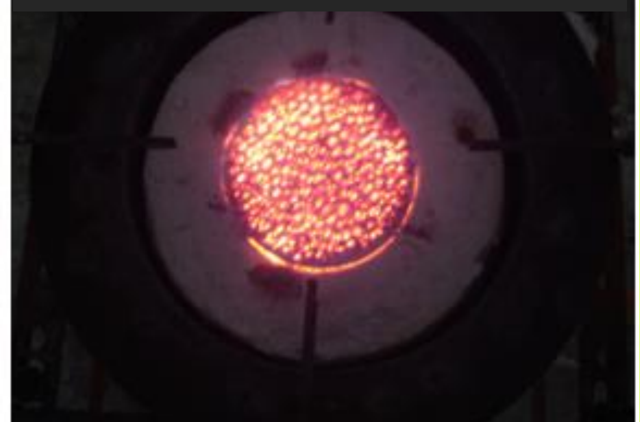
Solution: LPG/kerosene stoves with porous radiant burner

LPG stoves with conventional burners

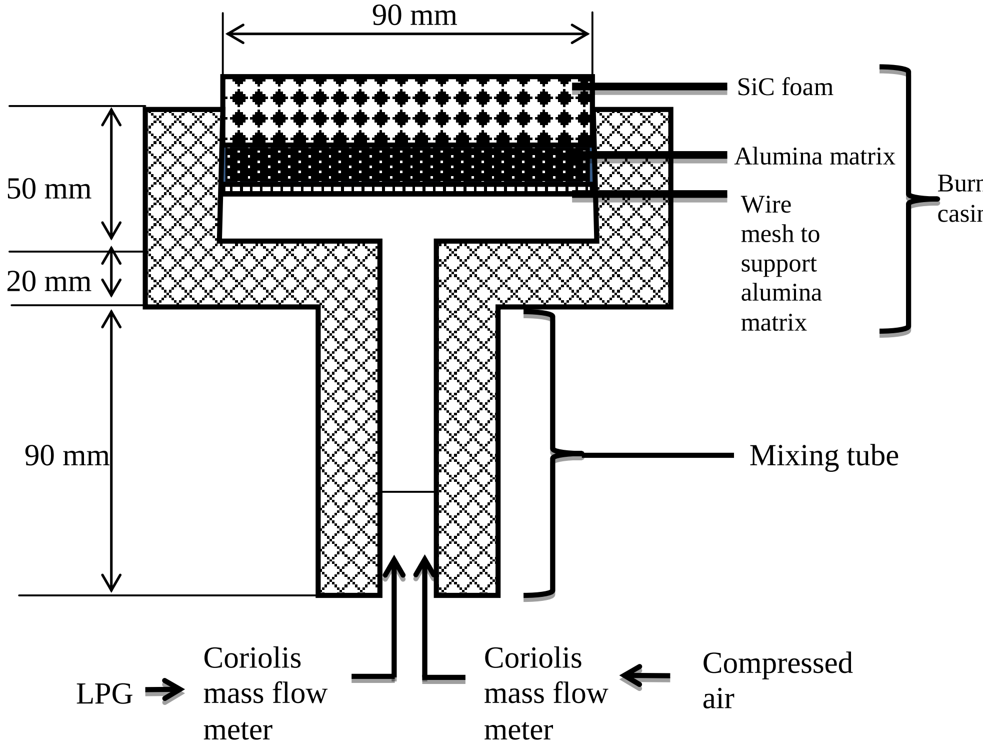


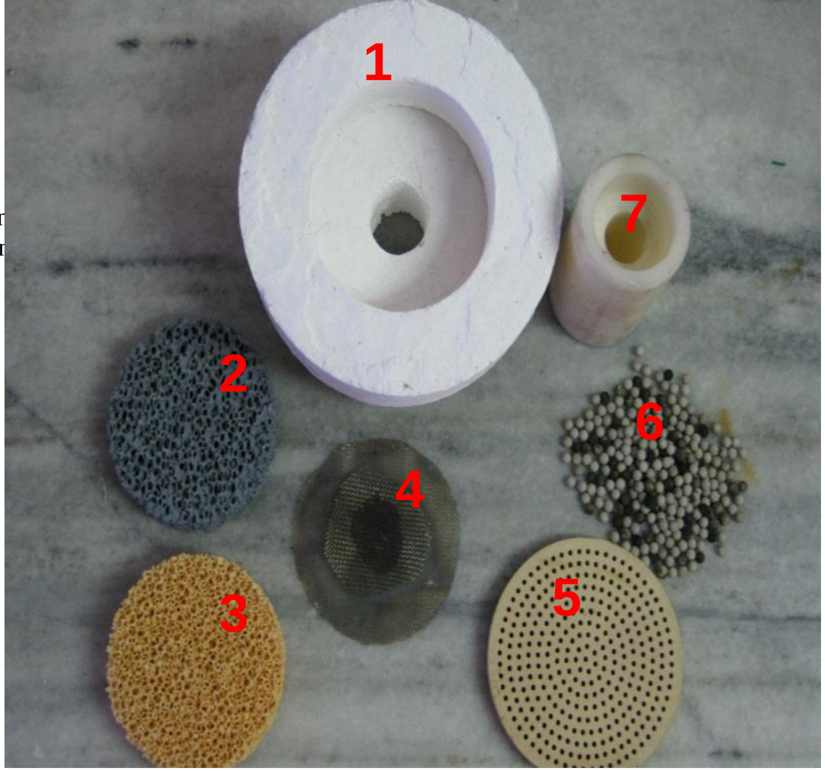
Free flame combustion NOT efficient

Combustion in porous media is efficient



Solution: LPG/kerosene stoves with porous radiant burner





Design details of Porous Radiant Burner

1.Burner casing 2. SiC foam 3.ZrO_2 foam 4. Wire mesh
5.Alumina matrix 6.Alumina ball 7.Mixing tube

EXPERIMENTAL SET UP

Muthukumar and Shyamkumar, **Fuel, 2013;112:562-566**

EXPERIMENTAL SET UP : A Picture Showing Red Hot PRB

Flow meter for Air

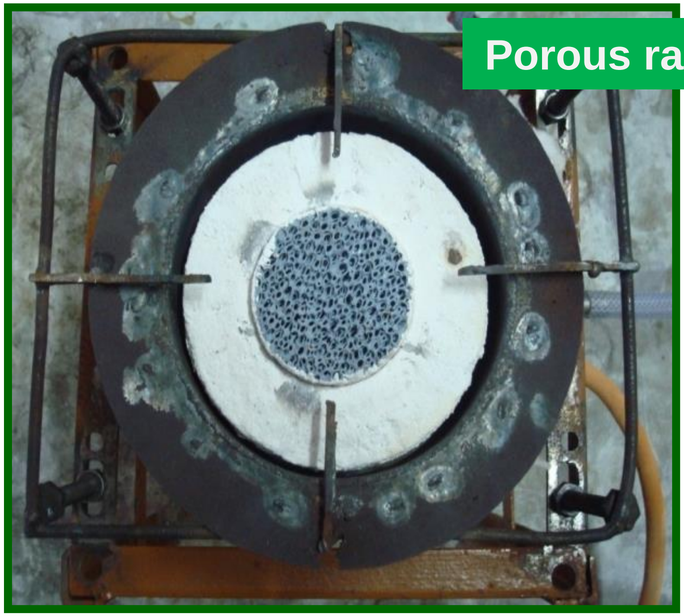
Flow meter for LPG

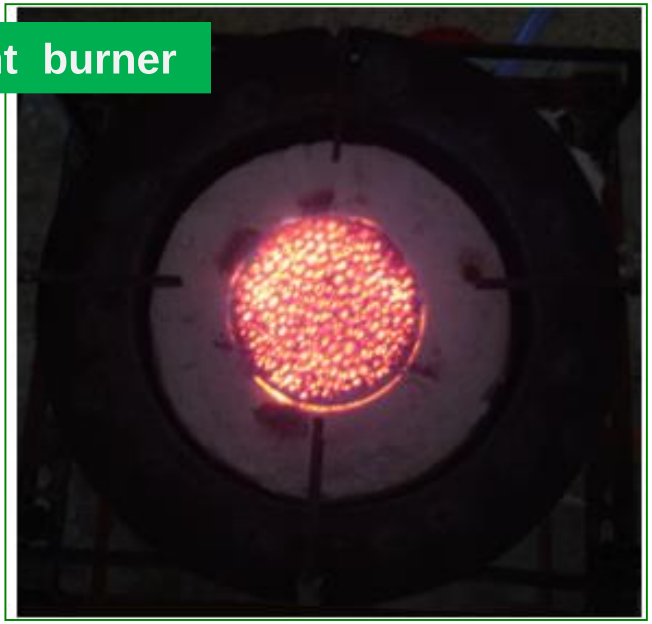
Red Hot PRB

Photographs of PMB and the conventional domestic burner

Conventional burner

Porous radiant burner





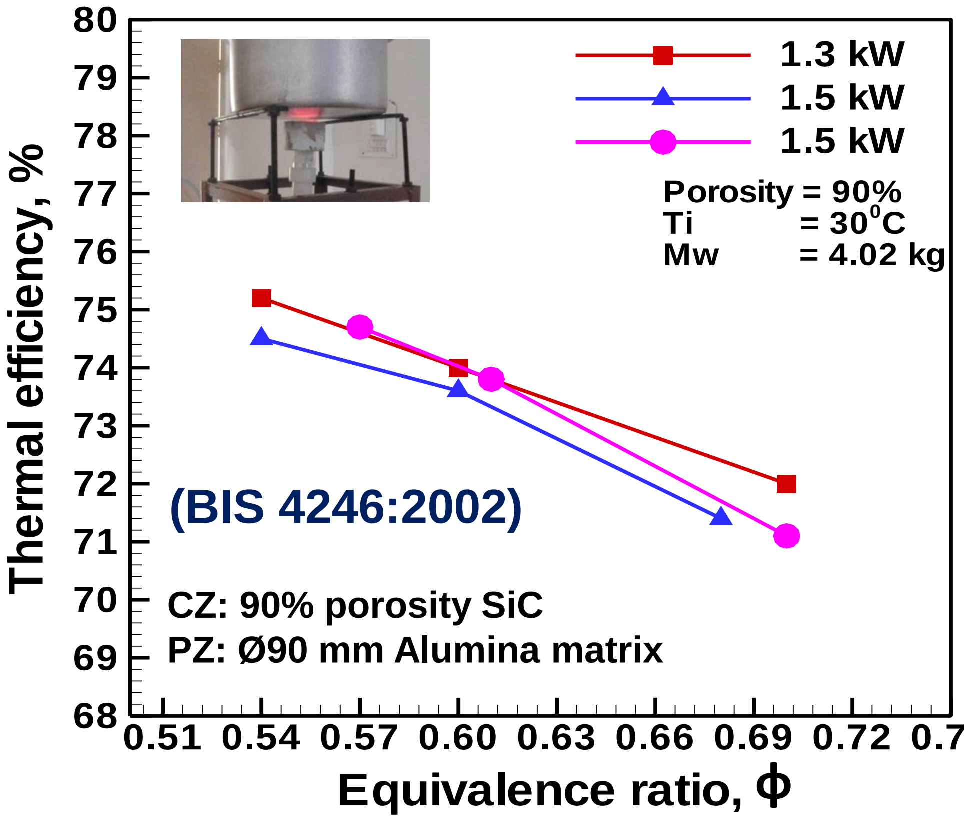
$$\eta_{th} = \frac{(m_w C_{pw} + m_v C_{pv})(T_2 - T_1)}{m_f \cdot CV} \times 100$$

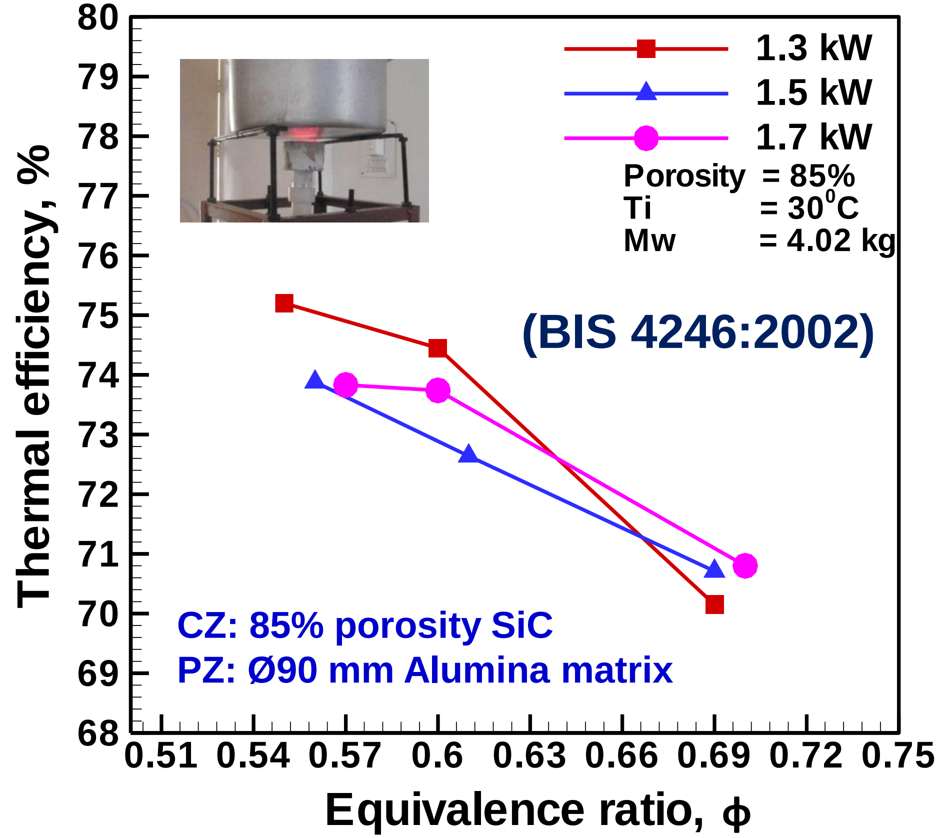
Conventional Burner

Efficiency : 50-65%

CO Emission : 400 to 1050 mg/m^3

NOx Emission : 160 to 220 mg/m^3





- **Combustion Zone: SiC (different porosity) and ZrO_2 (90%)**
- **Preheating Zone : Alumina Balls and Alumina Matrix (40%)**
- **Equivalence ratio ϕ: 0.5 – 0.7, Wattage: 1.3 kW – 1.7 kW.**

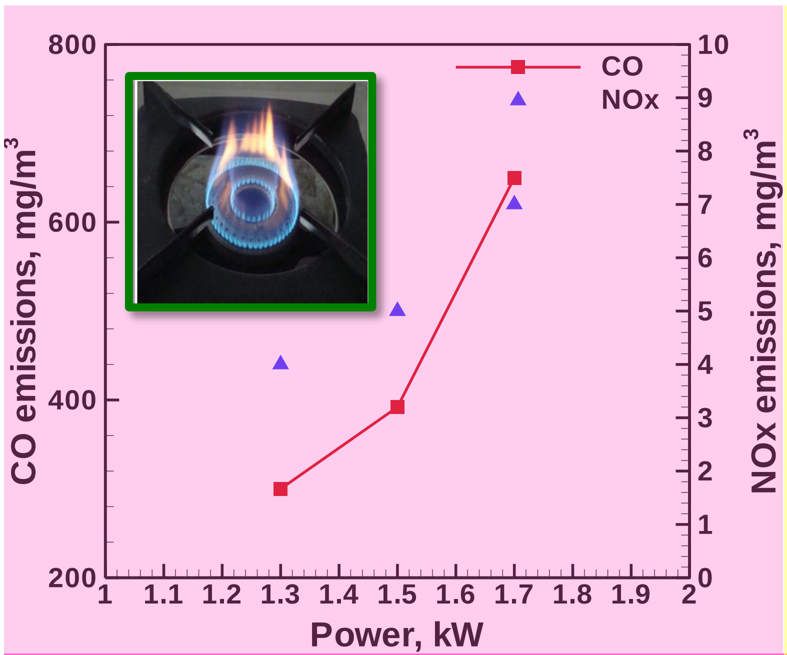
$$\phi = \frac{(A/F)_{Stoich}}{(A/F)_{Actual}}$$

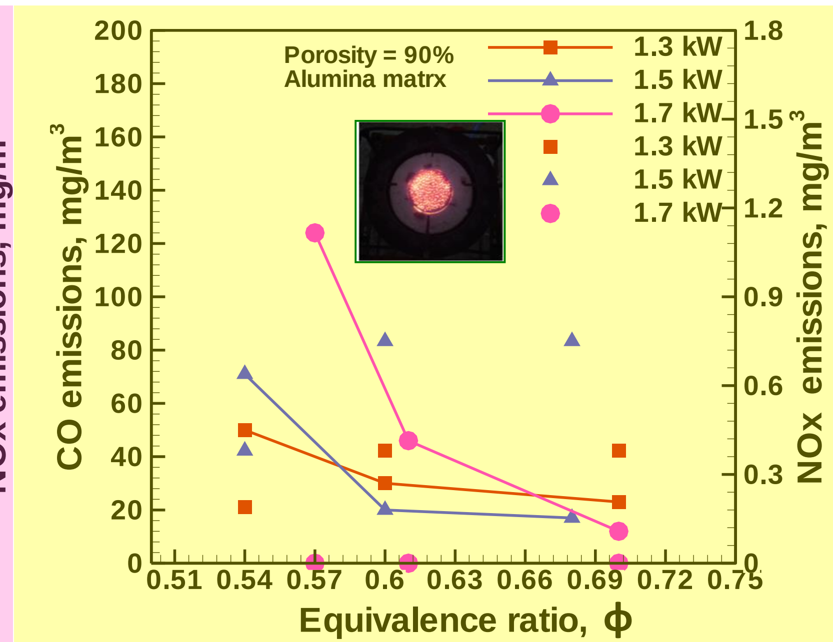
Muthukumar and Shyamkumar, Fuel, 2013;112:562-566

Emissions

The flue gas sampling was done according to the IS: 4246:2002

A portable flue gas analyser (TESTO) was used for measuring CO and NOx emissions.





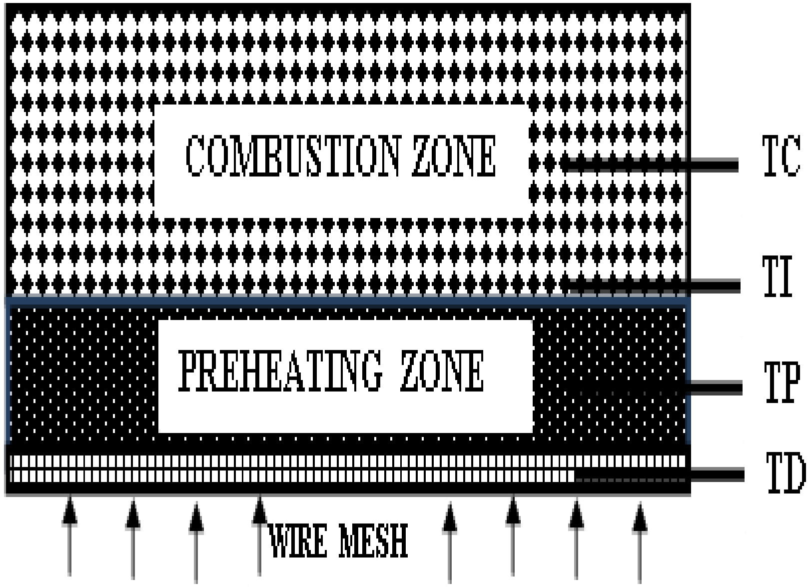
Conventional Burner

CO Emission : 300 to 1050 mg/m^3
NOx Emission : 4 to 220 mg/m^3
Efficiency : 50-65%

PRB with 90% porosity

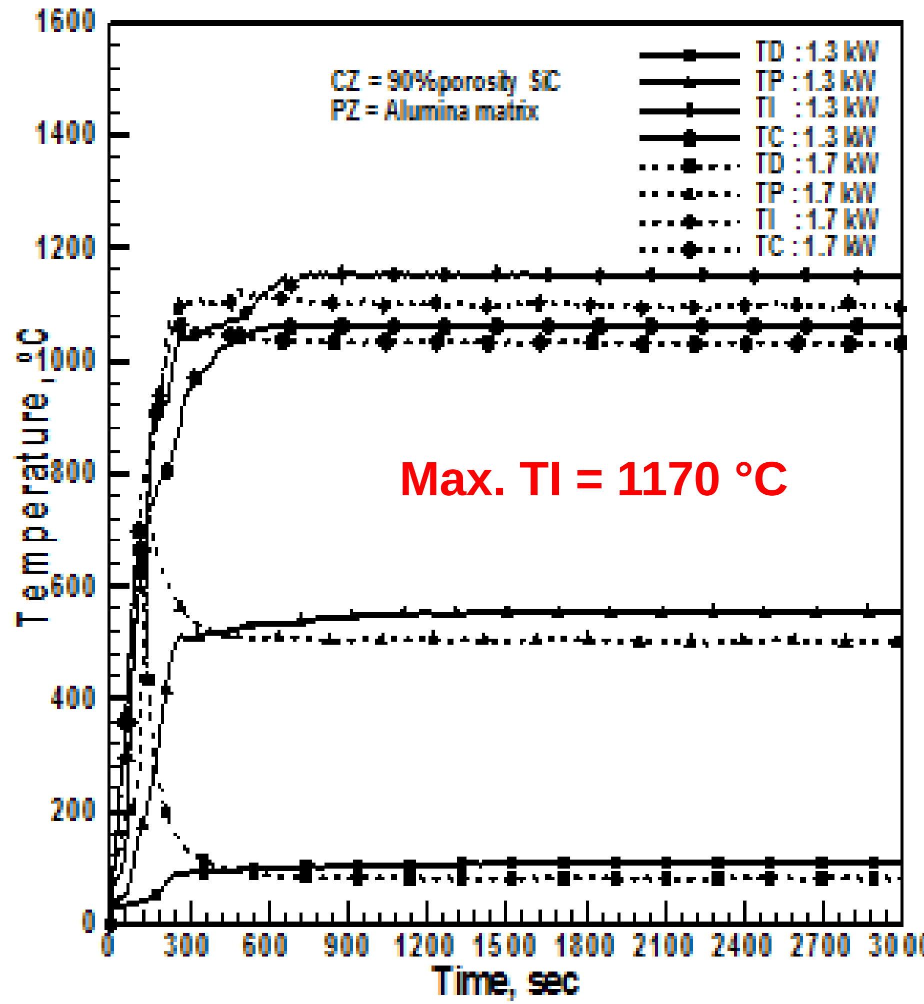
CO Emission : 10 to 140 mg/m^3
NOx Emission : 0.1 to 0.9 mg/m^3
Efficiency : 70-75%

Axial Temperature Distribution



- Combustion zone (TC)
- Preheating zone (TP)
- Down side of the wire mesh (TD)
- Interface of the two zones (TI)

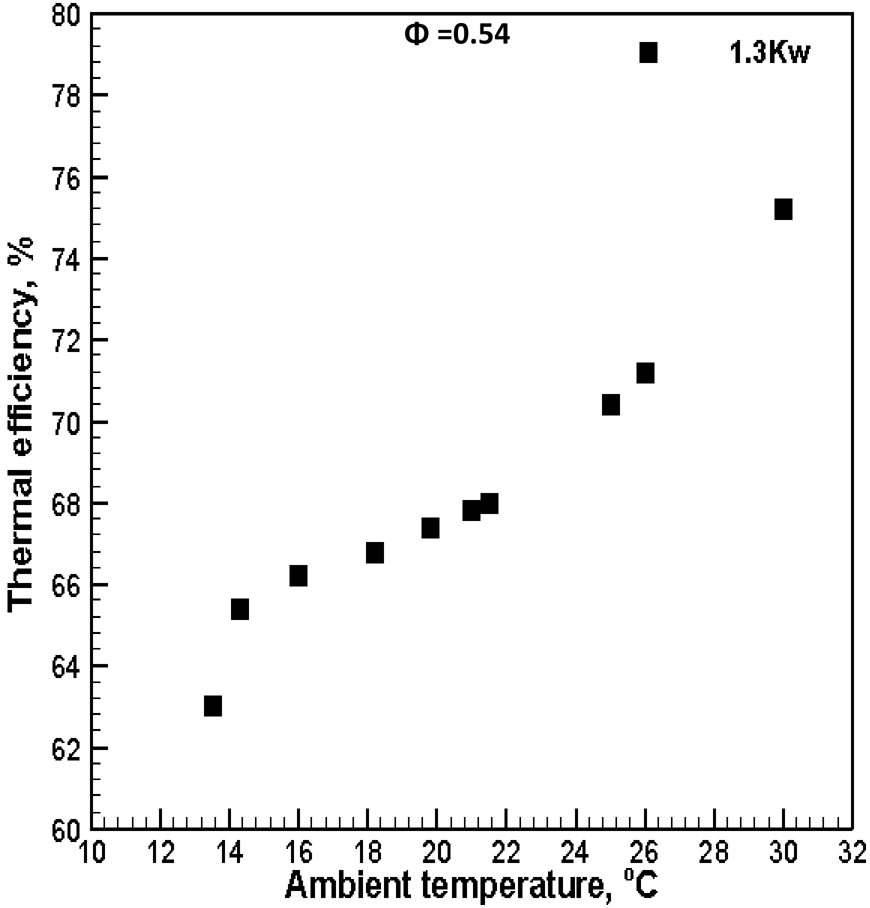
- Temperature at TI showing higher than any other regions



90% porosity burner (PPZ – Alumina matrix)

Effect of Ambient Temperature on Thermal Efficiency

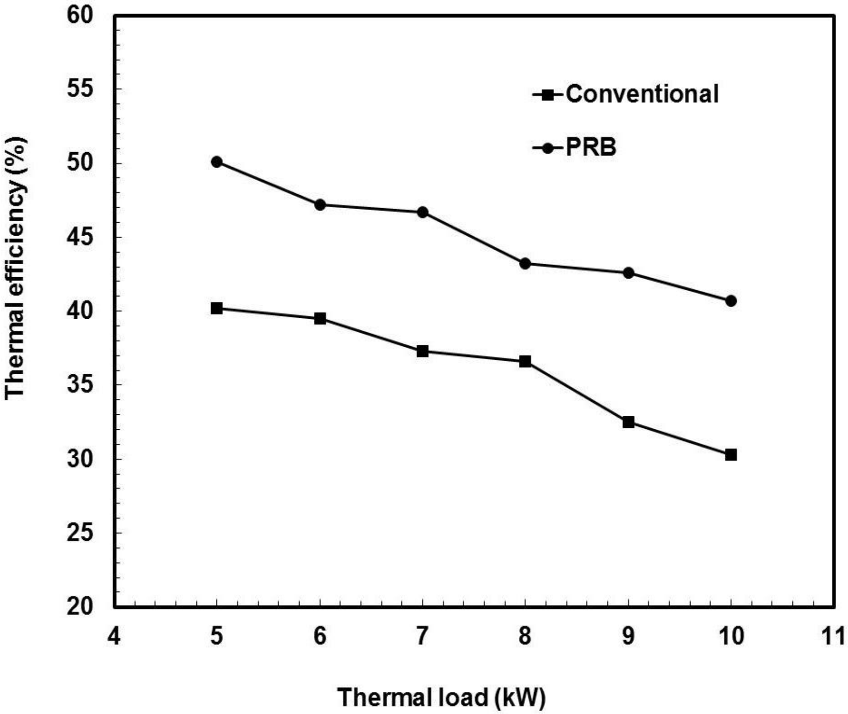
- **A series of experiments were carried out at wide range of ambient temperatures from 13.5 °C to 30 °C**
- **Thermal efficiency of the PB is directly proportional to ambient temperature.**
- **The maximum thermal efficiency was found to be 75% at 30 °C and 63% at 13.5 °C.**

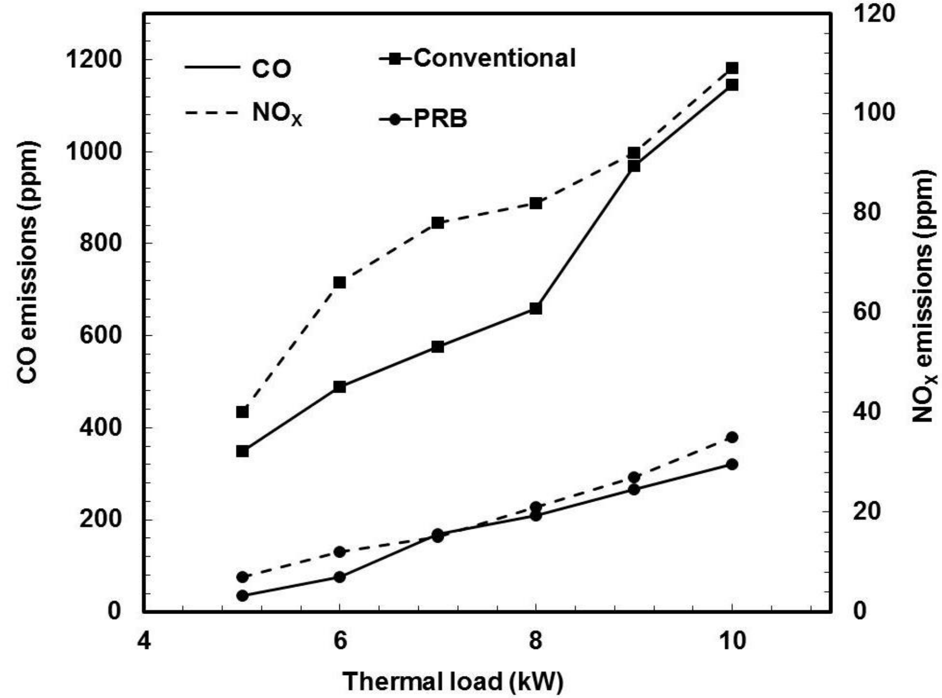


SiC,CZ-90% PZ Alumina matrix

Commercial burner available in Indian market chosen for comparison

At the thermal load of 10 kW, the PRB yielded the maximum improvement in thermal efficiency of about 34.3 %.





Energy Savings with Less Emissions

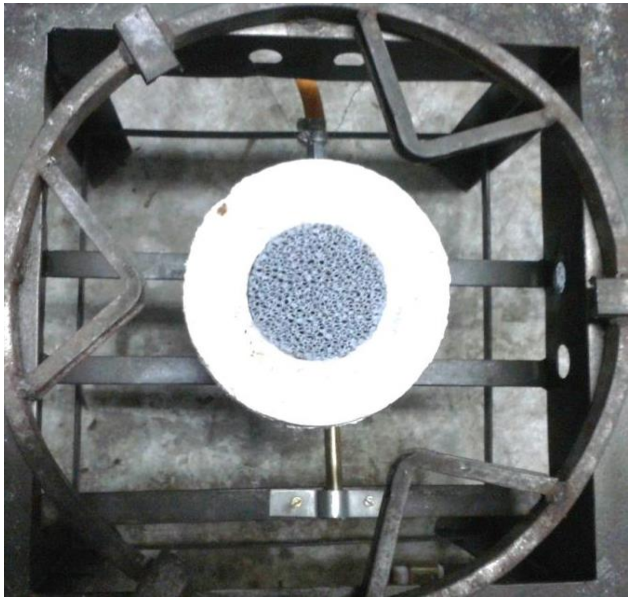
- The newly developed porous radiant burner (PRB) for LPG cooking stoves has been found to have the maximum thermal efficiency of ~ 75 % which is 15% higher than the conventional burner.
- Measured CO and NOx emissions of the PRB were in the range of 25-150 mg/m^3 and 0-2 mg/m^3. While, the respective values of the conventional burners are in the range of 400-1100 mg/m^3 and 75-260 mg/m^3.
- In terms of both thermal efficiency and emissions, the PRB has been found to be better than its conventional counterparts.
- Compared to a conventional burner, the newly developed PRB saves about 2 kg of LPG per cylinder (14.5 kg capacity).

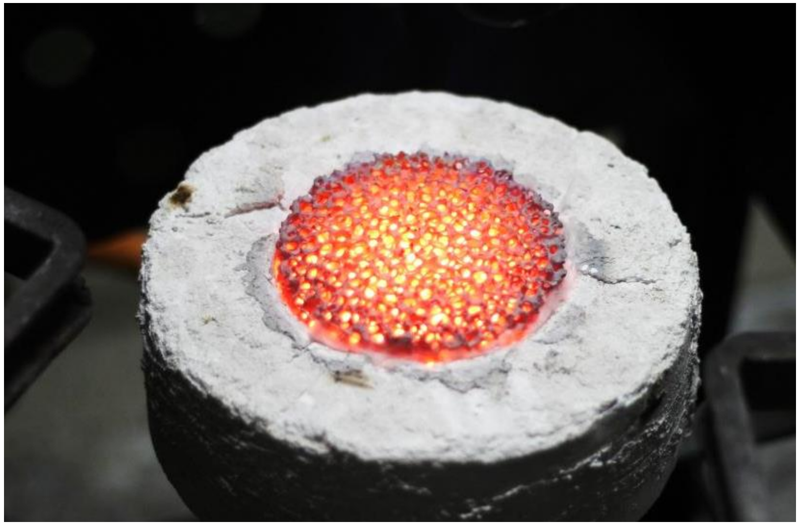
Required modifications before commercialization

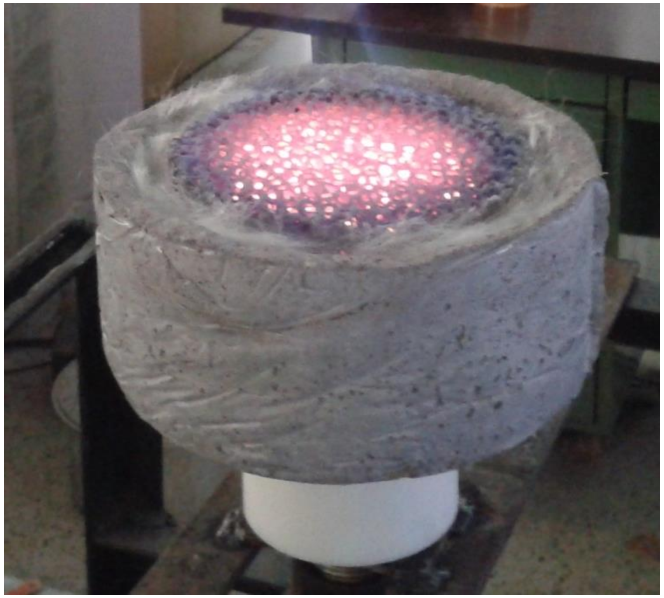
Burner to be made free from the external air supply

- PRB, the combustion is happening completely within the porous matrix. The entrained air is NOT enough to give flameless combustion.
- The porous matrices in the preheating zone and combustion zone added to the flow resistance.
- To overcome the flow resistance offered by the porous matrices, the air was supplied at ≈1.2 bar.
- For domestic cooking, it CANNOT be commercialized unless it works without any external air supply.

PRB Without External Air







- Modified pressure regulator, nozzle diameter and mixing chamber.
- Achieved flameless combustion with natural entrainment.
- Achieved 73-74 % thermal efficiency and less emissions
- Showed stable operation
- Power modulation is being investigated.

Brief Biography : Dr.P.Muthukumar

Ph.D Studies on Metal Hydride based Thermal Devices for Compression and Storage of Hydrogen, IIT Madras, Dec.2004.

Teaching / Research Experience

Associate Professor	: IIT Guwahati, from 9-01-2010 onwards
Assistant Professor	: IIT Guwahati from 27-01-2006 to 8-01-2010
Senior Project Officer	: IIT Madras from 1-07-2004 to 23-01-2006

Student Guidance

PhD : 3-Awarded; 2 –Thesis submitted; 2- Advance stage; 4-Ongoing.

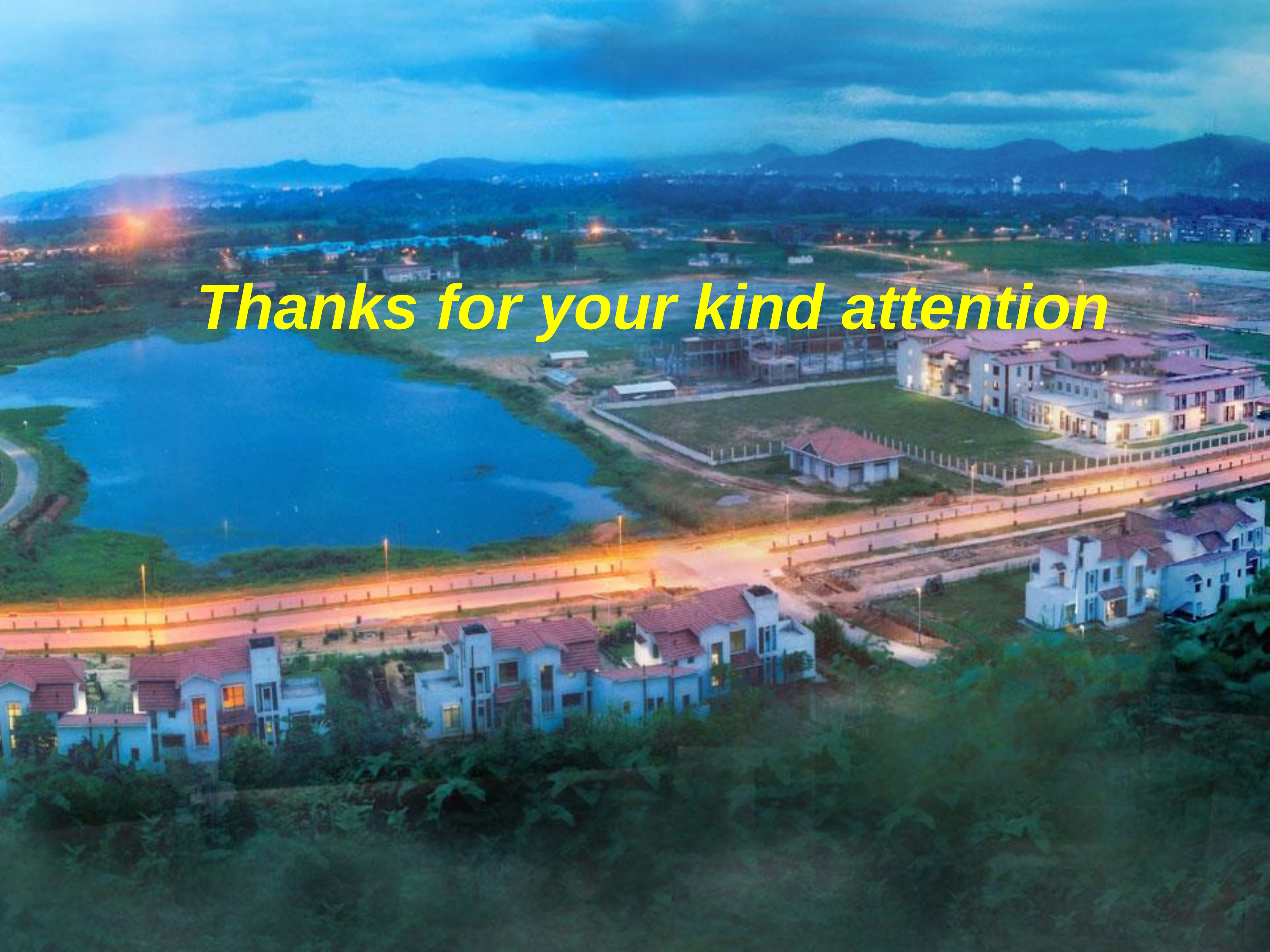
M.Tech : 25-Completed; 3-ongoing ; B.Tech : 15-Completed; Project staffs : 4

Research Contributions

Int Journals	: 40 + 10 Communicated (citation = 431)
Int Conference / workshops	: 56
National Conference	: 6
Patents	: 1 (Patent Number: 173/KOL/2013)
Completed Projects	: 4 Sponsored (63.35 L) + 3 Consultancy (7 L)
Ongoing Projects	: 1 Sponsored (128 L)
Projects under evaluation	: 2 sponsored (337 L) + 1 consultancy (36 L)

Awards / Fellowships received

- Received DAAD Research Fellowships 3 times (2008, 2010, 2012)
- Young Engineer Award -2012, from Senior Engineers Forum of Greater Guwahati
- Commission Member from India to work with the International Institute of Refrigeration (IIR)
- Represented India in Spain at Indo-Spain joint Workshop on Renewable Energy during March-11
- IEI Young Engineer Award-2010 in Mechanical Engg., from Institute of Engineers (India)
- DST-DAAD Project based Fellowship- 2000.


Thanks for your kind attention