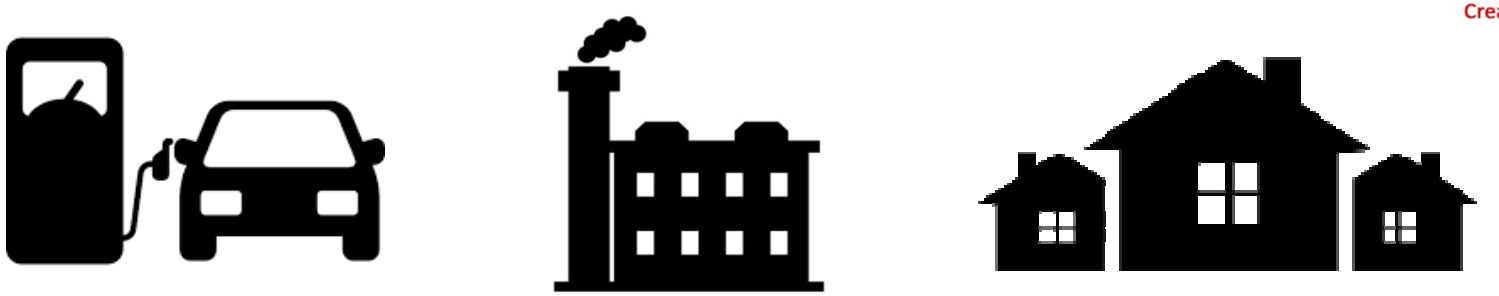
Development of Novel Fuel Efficient Domestic Cooking Burner for PNG (Piped Natural Gas) and Commercialization in India

CSIR- Indian Institute of Petroleum
Dehradun-248001

Indian Natural Gas Sector



Natural Gas Statistics of India, FY 2021-22

Total consumption of Natural Gas in India in FY 2021-22	**63.91 BCM**
Indigenous Production of Natural Gas FY 2021-22	34.02 BCM
Total gas consumption by the Energy Sector FY 2021-22	~50 BCM
Domestic PNG Connections in India as on Yr: 2022	**~1 Crore**
Average daily PNG consumption for a family of 4 persons	0.50 SCM /day
Total PNG consumption in India by domestic users	5 MSCM/day
CO2 produced by the combustion of PNG in domestic sector	~11,000 tones/day

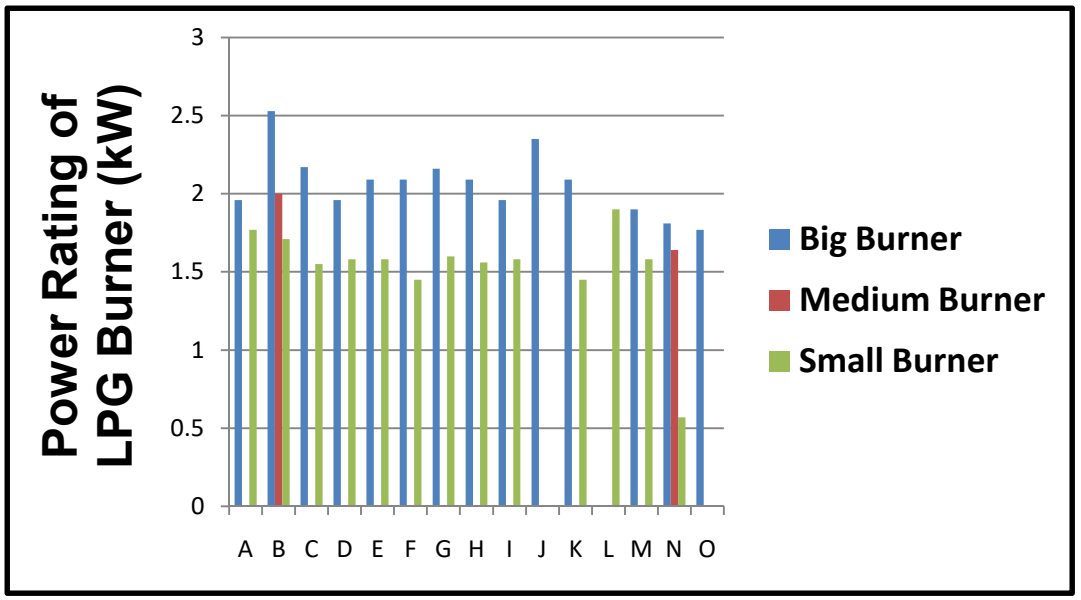
Reference: *Annual Report 2021-22, Ministry of Petroleum and Natural Gas, Indian PNG statistics 2021-22, MoPNG*

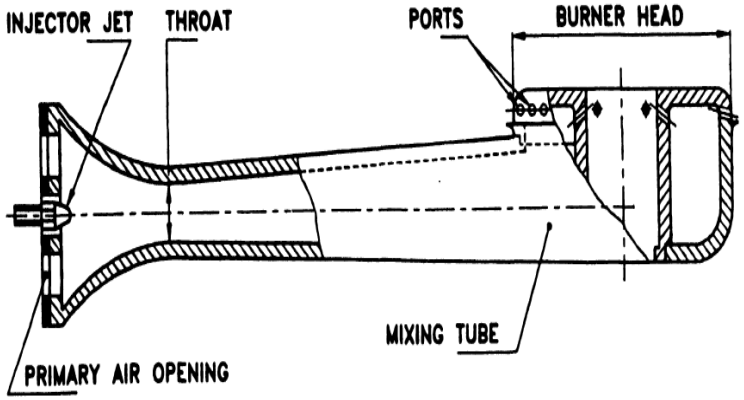
Current Practice in Indian Household

Creating Future Fuels

❑ LPG stoves are being used for firing PNG at household with retrofitting

- Not based on technical knowledge
- Thermal Performance of Stove Changes
- User Safety Compromised
- Tempering with a Standard Product





LPG v/s PNG

Creating Future Fuels

Comparison of LPG and PNG

Characteristics	LPG	PNG
Composition	Propane (40%) Butane (60%)	Methane (90%)
Gross Calorific value	93 MJ/m3	38 MJ/m3
Specific Gravity	1.5 - 2.0	0.5 - 0.6
Air : Fuel Ratio (vol.)	24 : 1	10 : 1
Flame Temperature	1950°C - 2000°C	1900°C - 1950°C

- Compared to LPG, PNG has lower Calorific Value
- PNG is lighter than LPG
- Different Air-Fuel requirement for Combustion
- Different fuel supply pressure
- Requires a dedicated appliance for efficient & safe firing application

Wobbe Number

$$Q_g = A_o V_g = A_o \left(\frac{2P_f}{Cd_g}\right)^{1/2}$$

Where $K = A_o H \left(\frac{2P_f}{Cd_a}\right)$ and specific gravity of gas $S = \frac{d_g}{d_a}$

$$Q_{th} = K\, H\, /\, \sqrt{S}$$

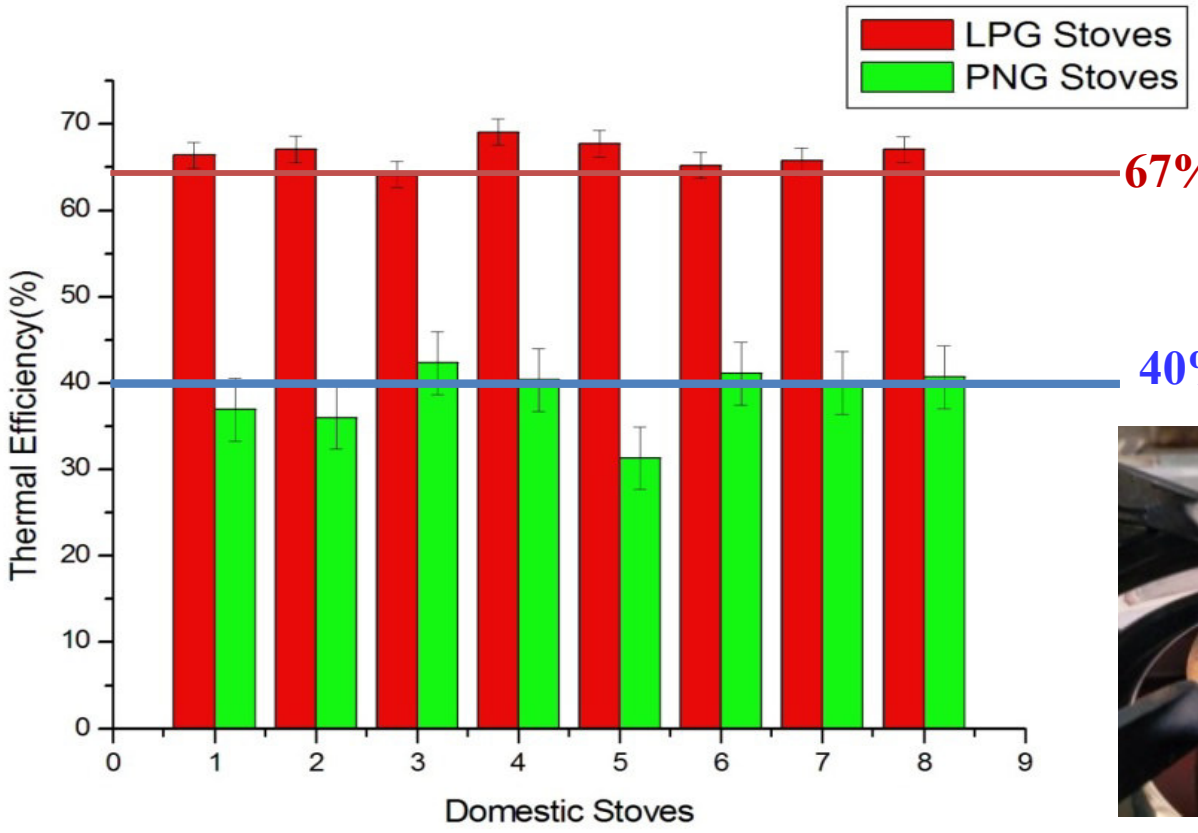
$$\mathrm{H}/\sqrt{\mathrm{S}} = \textit{Wobbe No.}$$

The correction factor C is determined from C = 1 + 4/Re

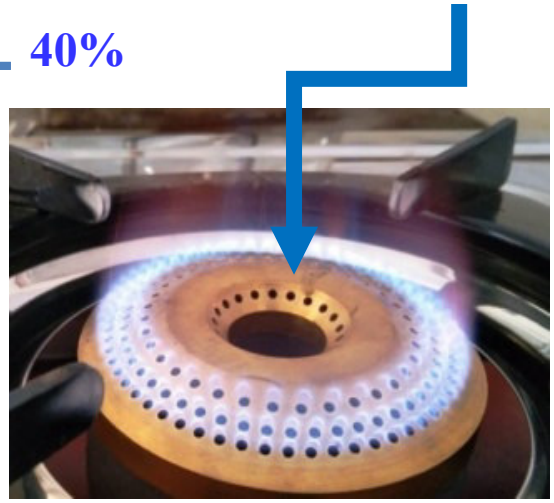
The thermal input of the burner remains constant as long as the ratio $HS^{-1/2}$ remains constant

	PNG	LPG
Wobbe No.	54	81

Thermal Efficiency of Burner



Burner holes without flame



Thermal efficiency reduces from 25-30% when LPG stoves are used to fire PNG

Flame Lift in Burner

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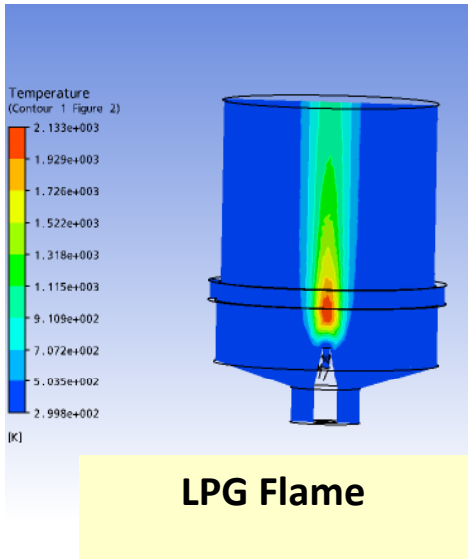
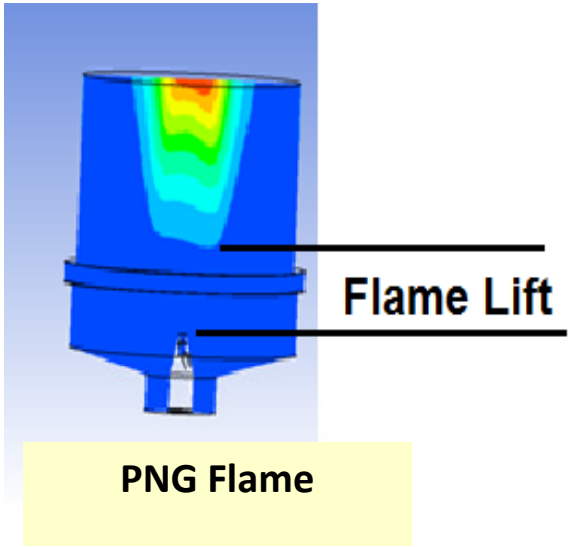


LPG Flame



PNG Flame

User safety is compromised with "Flame Lift" and Flame Failure due to different burning velocities

Problem Definition & Objectives

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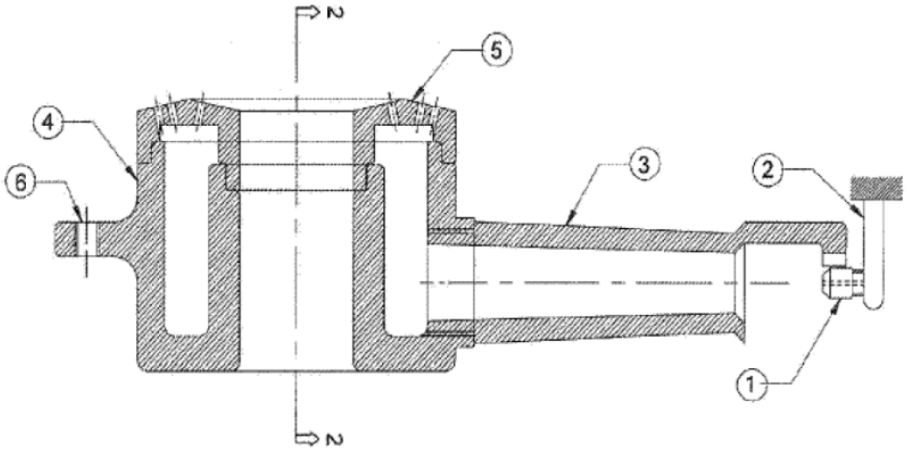
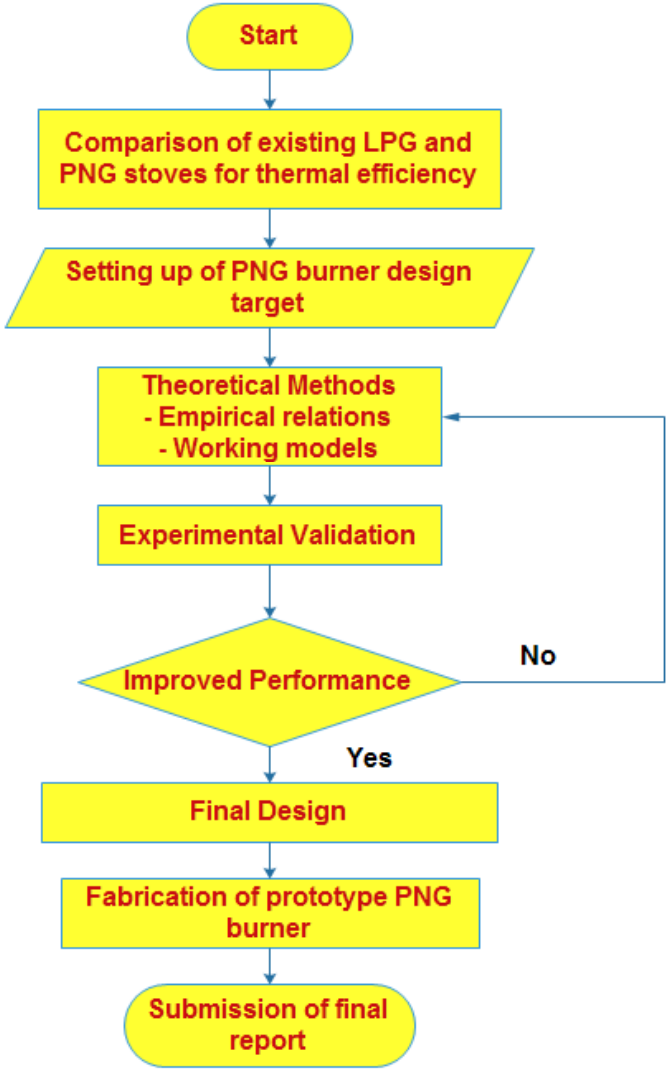
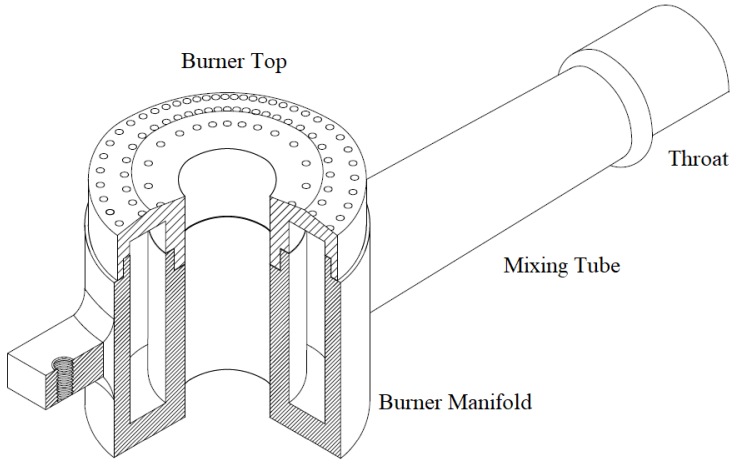


(1) Gas Injector (2) Gas Pipe (3) Mixing Tube (4) Gas Manifold (5) Burner Top



Burner Design for Natural Gas

(1.82 kW of Power Rating)



Heat Release:

$$HR = m \times HV \quad Q = 180\ l/h$$

HR = 1.82 kW, HV= 36.46 MJ/m3

Critical Pressure:

$$Pc = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}} = 0.55, \frac{P_b}{P_t} = 0.96, P_c < \frac{P_b}{P_t}$$

Mass flow rate through nozzle:

$$\mathrm{m} = C_d \times \rho_e \times A \times M_e \times C_e$$

$$\boldsymbol{d_o \sim 1\ mm}$$

Throat Diamter:

$$r = \sqrt{s}\left(\frac{d_t}{d_o} - 1\right) \quad d_t = 8.23\ mm$$

Burner Design for Natural Gas

Creating Future Fuels

Burner Port:

$$A_p > \frac{Q_m}{V_p} \qquad 0.0029\ \text{m}^2$$

$$A_{total} = \frac{N\pi D^2}{4}$$

Velocity at the orifice:

$$V_o = \frac{Q}{3.6\times10^{-3}A_o} = 63.69\ \text{m/s}$$

Primary Aeration:

$$P_a = \frac{r}{\left(\frac{A}{F}\right)_{Stoic}} \times 100$$

For 50% primary aeration, flow of fuel air mixture

$$Q_m = \frac{Q\,(1+r)}{3600}\,m^3/s \qquad = 3.2\,\text{X}10^{-4}\,m^3/s$$

Pressure Drop in Throat:

$$P_t = P_o - \frac{V_o}{2g}\left[1 - \left(\frac{d_o}{d_t}\right)^4\right]$$

Reynolds No:

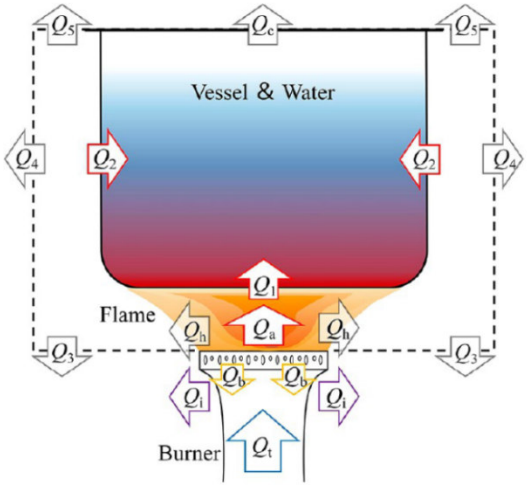
$$R_e = \frac{4\rho Q_m}{\pi\mu d_t}$$

By putting all the values, $R_e = 1731.76$, Which indicates the flow is laminar,

$$\Delta_p = \rho \times \frac{f}{2} \times \frac{16\,Q_m{}^2}{\pi^2 d_t{}^5} \times L_m \qquad 0.32\ \text{P}_\text{a}$$

This is very less compared to driving pressure of 230 Pa

Experimental Study



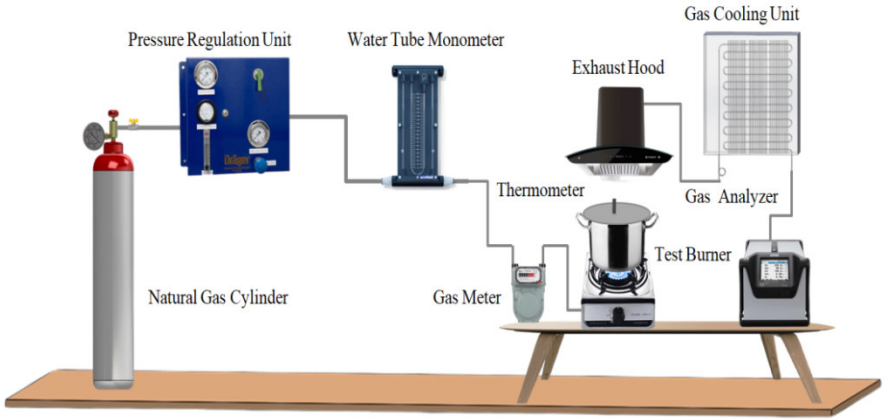
Heat Transfer & Thermal Efficiency

Heat Input: $Q_a = Q_1 + Q_2$

Through Convection

Heat Loss: $Q_h = Q_3 + Q_4 + Q_5$

Through Radiation + Convection



Experimental Set up

$$\eta\% = \frac{(G + W) \times (T_1 - T_2)}{M \times K} \times 100$$

η = *Thermal efficiency of the burner*

G = *Quantity of water in vessel in kg*

W = *Water equivalent of the vessel complete with lid and stirrer*

T_2 = *Final temperature of water in °C*

T_1 = *Initial temperature of water in °C*

M = *Gas consumption in liters*

K = *Calorific Value of the gas in kcal/l*

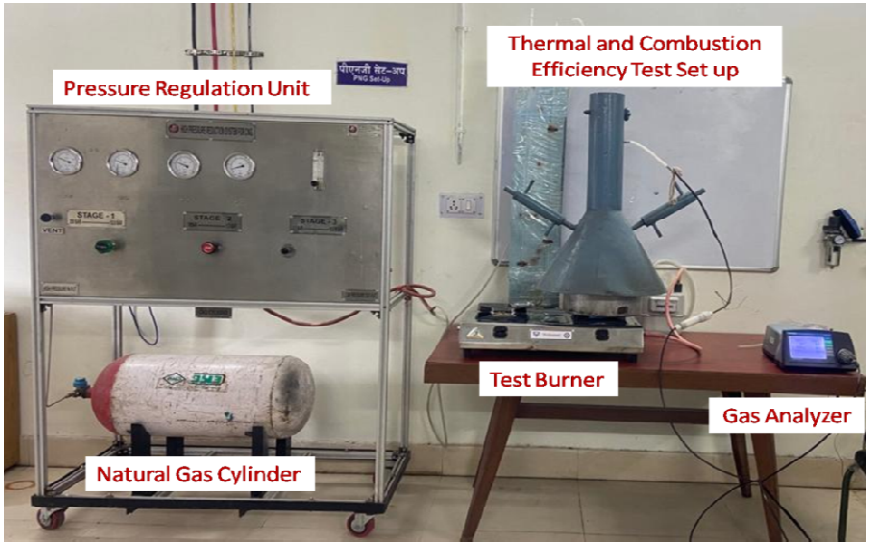
Thermal Efficiency

Table. GC analysis of the Piped Natural Gas samples and its properties

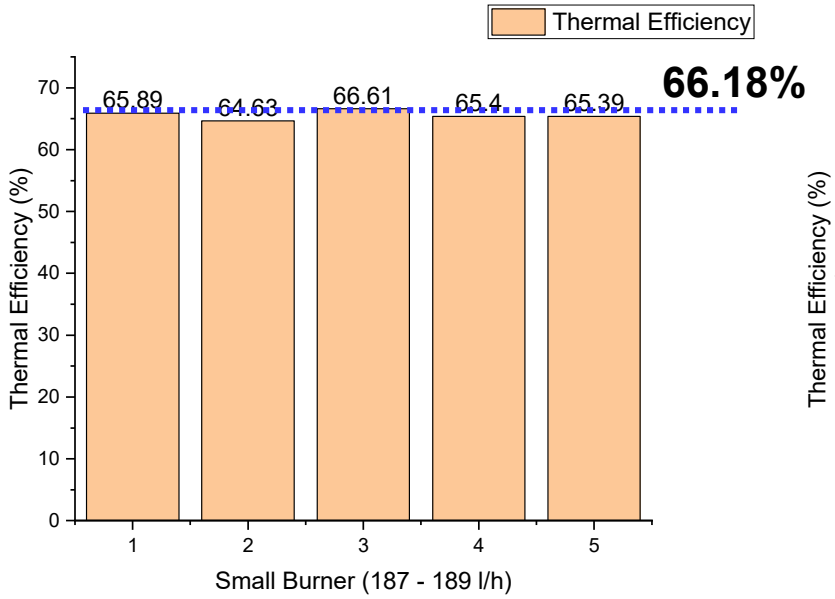
Constituents	Mass %	Molar Mass	Calorific Value MJ/m³	Gas Density at STP	Specific Gravity at STP
Methane	92.87	16.04	802.65	0.668	0.55
Ethane	05.58	30.07	1428.74	1.264	1.04
Propane	00.81	44.09	2043.23	1.882	1.56
I-butane	00.16	56.10	2540.86	2.33	1.94
n-Butane	00.18	58.12	2657.45	2.33	1.94
i-pantene	00.36	70.13	3155.45	2.99	2.49
n-pantane	00.01	72.15	3271.83	2.99	2.49
Total	100.00	17.40	36.46	0.72	0.60

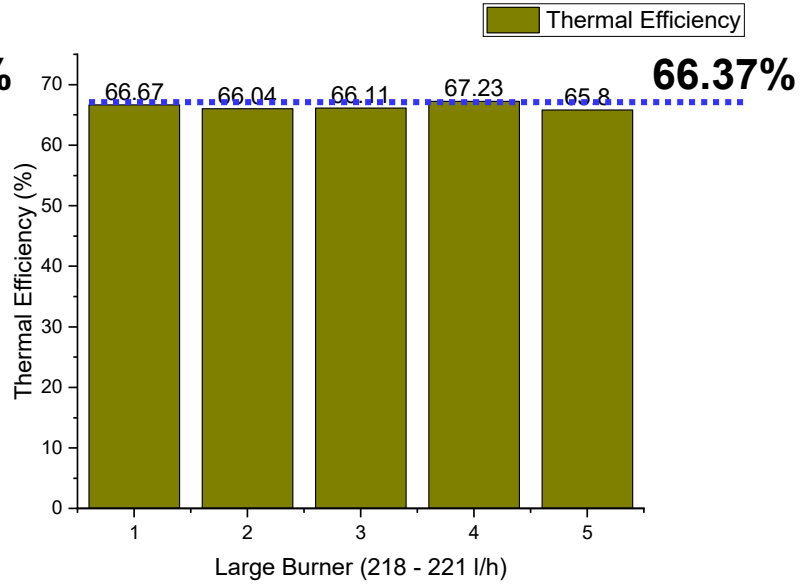
Table. Selection of test vessel

The gas rate at STP l/h (1)	Pan Diameter (external) mm, ±5% (2)	Pan Height (external) mm, ±5% (3)	Total Pan Mass with LID G, ±10 (4)	The mass of water in Pan kg (5)
Up to 150	180	100	356	2.0
151 to 170	205	110	451	2.8
171 to 180	220	120	519	3.7
181 to 190	245	130	632	4.8
191 to 200	260	140	750	6.1
201 to 210	285	155	853	7.7
211 to 230	295	165	920	9.4



Efficiency

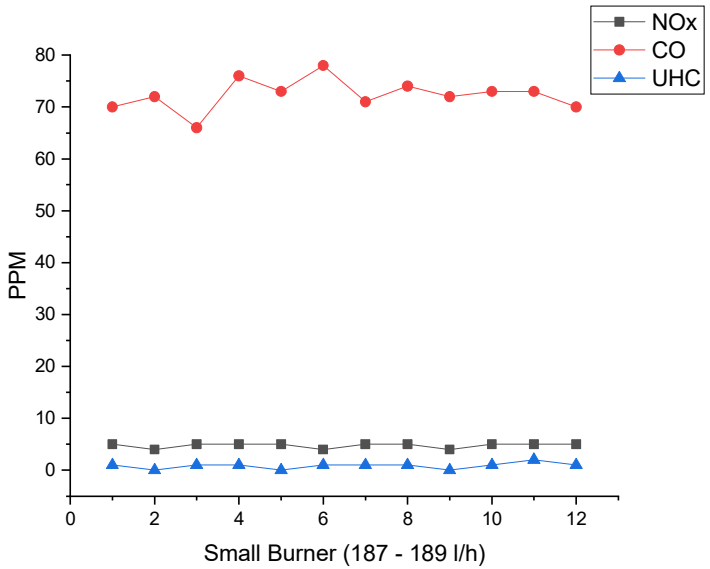


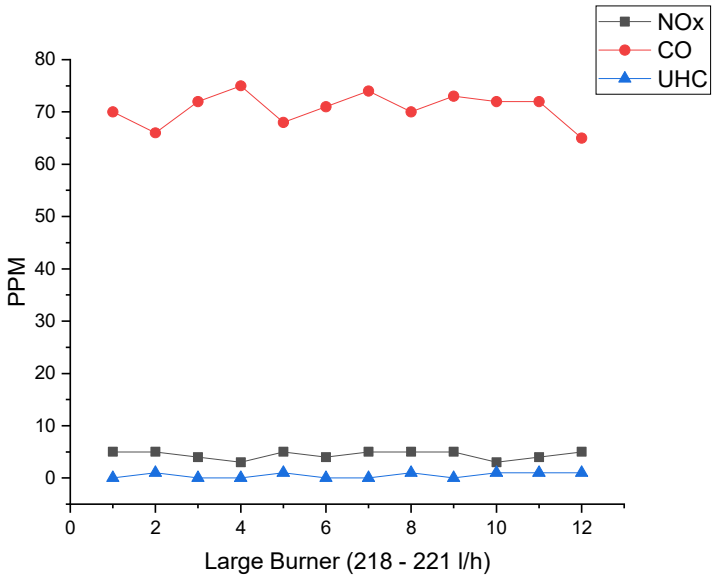


Thermal efficiency of test burners when tested as per IS 17153

Experimental Study	Burner Used	Fuel Used	Method	Result
Present Study	Self-aspiring Premixed	Commercial NG	IS 17153	65 – 67%
Fang et.al. [9]	TRPGB	Commercial NG	GB 16410-2020	64 – 66 %

Emissions

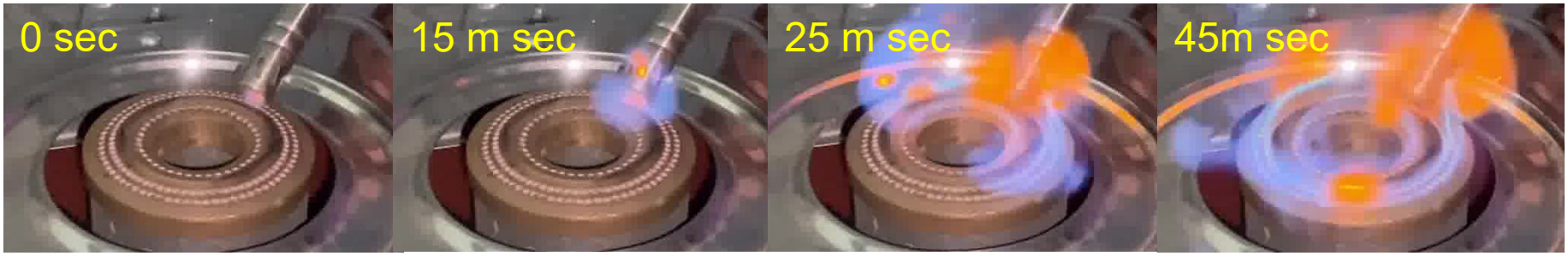




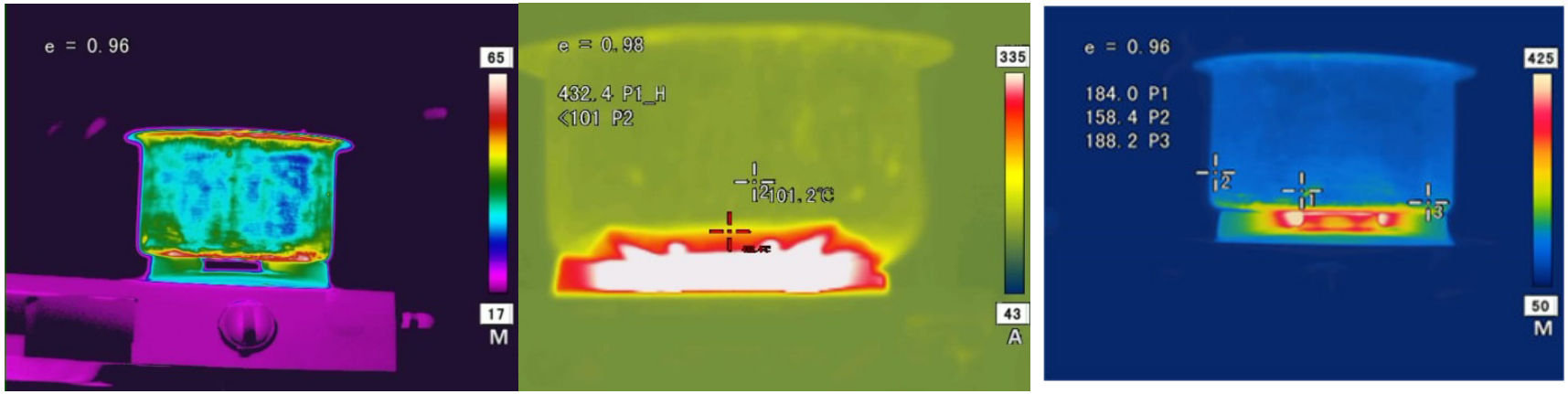
Emissions NOx, CO & Un-burnt Hydrocarbon UHC

Experimental Study	Fuel Used	Method	NOx (PPM)	CO (PPM)	UHC (PPM)
Present Study	Commercial NG	IS 17153	5 - 10	65 - 75	0 - 1
Glanville et.al. [9]	Commercial NG	---	10 - 15	35 - 100	--

Burner Ignition



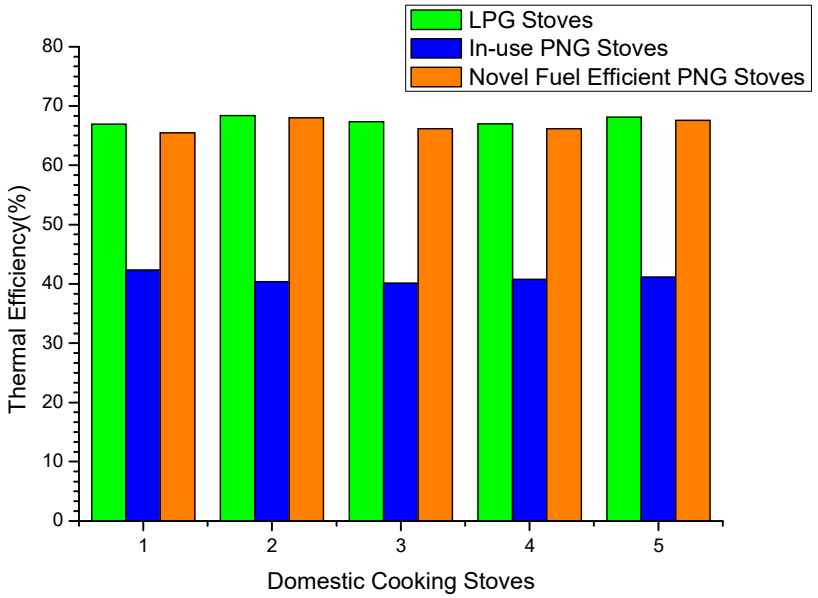
Flame ignition time with Natural Gas taken with high speed imaging camera



Temperature profile of vessel with Natural Gas taken with thermal camera

Performance of Designed Burner

Actual images of the fabricated burner



Comparative thermal performance of PNG burner

Intellectual Property Rights

Creating Future Fuels

पेटेंट कार्यालय,भारत सरकार
पेटेंट प्रमाण पत्र
The Patent Office, Government Of India
Patent Certificate

पेटेंट सं. / Patent No. : 461166
आवेदन सं. / Application No. : 201711046975
फाइल करने की तारीख / Date of Filing : 28/12/2017
पेटेंटी / Patentee : 1.COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH 2.PETROLEUM CONSERVATION RESEARCH ASSOCITATION

प्रमाणित किया जाता है कि पेटेंटी को, उपरोक्त आवेदन में यथाप्रकटित *A DOMESTIC COOKING BURNER FOR PIPED NATURAL GAS* नामक आविष्कार के लिए, पेटेंट अधिनियम, 1970 के उपबंधों के अनुसार आज तारीख दिसम्बर 2017 से अट्ठाईसवें दिन से बीस वर्ष की अवधि के लिए पेटेंट अनुदत्त किया गया है।

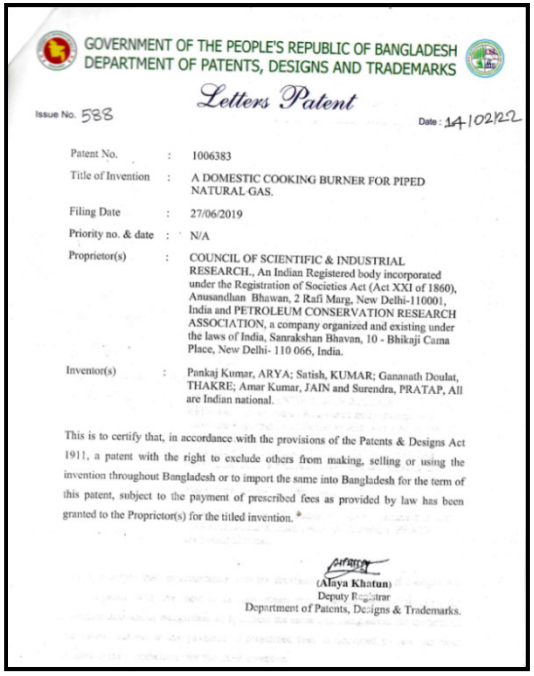
It is hereby certified that a patent has been granted to the patentee for an invention entitled *A DOMESTIC COOKING BURNER FOR PIPED NATURAL GAS* as disclosed in the above mentioned application for the term of 20 years from the 28th day of December 2017 in accordance with the provisions of the Patents Act,1970.

अनुदान की तारीख : 20/10/2023
Date of Grant :

Controller of Patents

टिप्पणी - इस पेटेंट के नवीकरण के लिए फीस, यदि इसे बनाए रखा जाना है, दिसम्बर 2019 के अट्ठाईसवें दिन को और उसके पश्चात प्रत्येक वर्ष के उसी दिन देय होगी।
Note. - The fees for renewal of this patent, if it is to be maintained, will fall / has fallen due on 28th day of December 2019 and on the same day in every year thereafter.

Indian Patent



GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
DEPARTMENT OF PATENTS, DESIGNS AND TRADEMARKS

Letters Patent

Issue No. 588 Date : 14/02/22

Patent No. : 1006383
Title of Invention : A DOMESTIC COOKING BURNER FOR PIPED NATURAL GAS.
Filing Date : 27/06/2019
Priority no. & date : N/A
Proprietor(s) : COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH., An Indian Registered body incorporated under the Registration of Societies Act (Act XXI of 1860), Anusandhan Bhawan, 2 Rafi Marg, New Delhi-110001, India and PETROLEUM CONSERVATION RESEARCH ASSOCIATION, a company organized and existing under the laws of India, Sanrakshan Bhavan, 10 - Bhikaji Cama Place, New Delhi- 110 066, India.
Inventor(s) : Pankaj Kumar, ARYA; Satish, KUMAR; Gananath Doulat, THAKRE; Amar Kumar, JAIN and Surendra, PRATAP, All are Indian national.

This is to certify that, in accordance with the provisions of the Patents & Designs Act 1911, a patent with the right to exclude others from making, selling or using the invention throughout Bangladesh or to import the same into Bangladesh for the term of this patent, subject to the payment of prescribed fees as provided by law has been granted to the Proprietor(s) for the titled invention.

(Alaya Khatun)
Deputy Registrar
Department of Patents, Designs & Trademarks.

Bangladesh Patent

FOREIGN PRIORITY NO: PCT/IN2019/050482 DATED:26.06.2019

PATENT FORM NO. 4

CRP: 006744

FEDERAL REPUBLIC OF NIGERIA
Certificate of Registration of Patent
(Patents and Designs Act; CAP 344 Laws of the Federation of Nigeria 1990)

RP: F/P/2022/5
Date of Patent: 22/12/2021
Date of Sealing: 05/05/2022

President of the Federal Republic of Nigeria and Commander-in-chief of the Armed Forces
MUHAMMADU BUHARI, *GCFR.*

Whereas a request for the grant of a patent has been made by **COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH [IN/IN] AND PETROLEUM CONSERVATION RESEARCH ASSOCIATION [IN/IN]** of **ANUSANDHAN BHAWAN 2 RAFI MARG NEW DELHI 110001 (IN) AND SANRAKSHAN BHAVAN 10- BHIKAJI CAMA PLACE NEW DELHI 110066 INDIA C/O STILL WATERS LAW FIRM OF 2ND FLOOR, 11 AWOLOWO ROAD, P.O.BOX 56161, IKOYI, LAGOS NIGERIA.**

For the sole use and advantage of an invention for, **A DOMESTIC COOKING BURNER FOR PIPED NATURAL GAS**

AND WHEREAS the Federal Government being willing to encourage all invention which may be for public good, is pleased to accede to the request:

KNOW YE THEREFORE, that I do by this Instrument give and grant unto the person(s) above named and any successor(s), executor(s), administrator(s) and assign(s) (each and any of whom are hereinafter referred to as the patentee) by special licence, full power, sole privilege and authority, that the patentee or any agent or licensee of the patentee may subject to the conditions and provisions prescribed by any statute or order for the time being in force at all times hereafter during the term of years herein mentioned, make, use, exercise and vend the said invention throughout the Federal Republic of Nigeria, and that the patentee shall have and enjoy the whole profit and advantage from time to time accruing by reason of the said invention during the term of twenty years from the date first above written on this Instrument: AND to the end that the patentee may have and enjoy the sole use and exercise of the full benefit of the said invention, I do by this Instrument strictly command all citizens of the Federal Republic of Nigeria that they do not at any time during the continuance of the said term either directly or indirectly make use of or put in practice the said invention, nor in anywise imitate the same, without the written consent, licence or agreement of the patentee, on pain of incurring such penalties as may be justly inflicted on such offenders, and of being answerable to the patentee according to law for damages thereby occasioned.

PROVIDED ALWAYS that this patent shall be revocable on any of the grounds from time to time by law prescribed as grounds for revoking patents granted by me, and the same may be revoked and made void accordingly:

PROVIDED ALSO that nothing herein contained shall prevent the granting of licences in such manner and for such considerations as they may by law be granted.

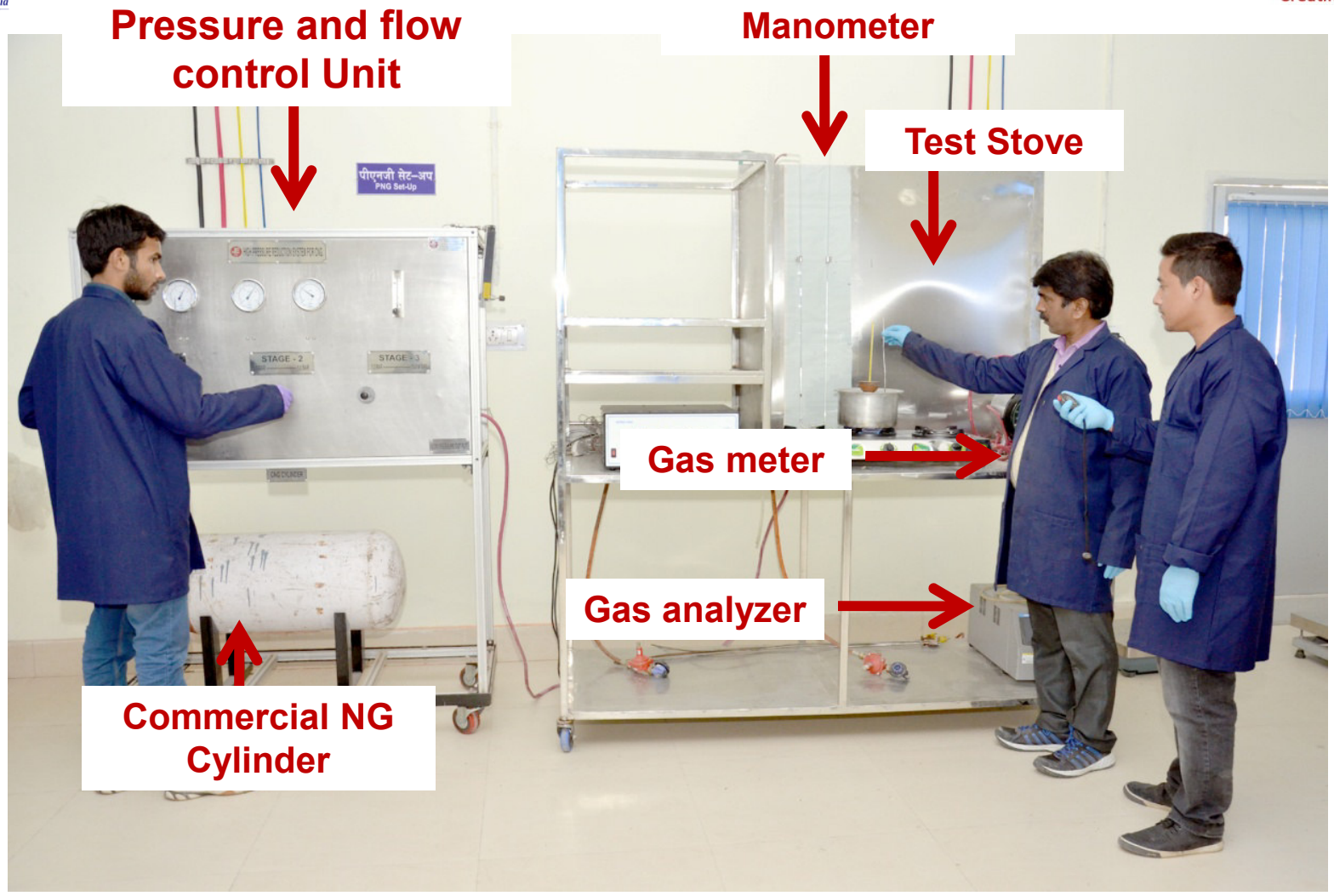
MADE this: 5TH DAY OF MAY, 2022

STELLA OZO EZENDUKA
Registrar

Nigeria Patent

- **Indian Patent Grated: No. 461166; dated 20.10.2023**
- **Design Registration in India vide Design No. 303178, Certificate No. 70838 Dated 5th March 2018**
- **Bangladesh Patent Granted, Patent No.: 1006383, dated: 14.02.2022**
- **Nigeria Patent Granted, PCT/IN2019/050482, dated: 05.05.2022**

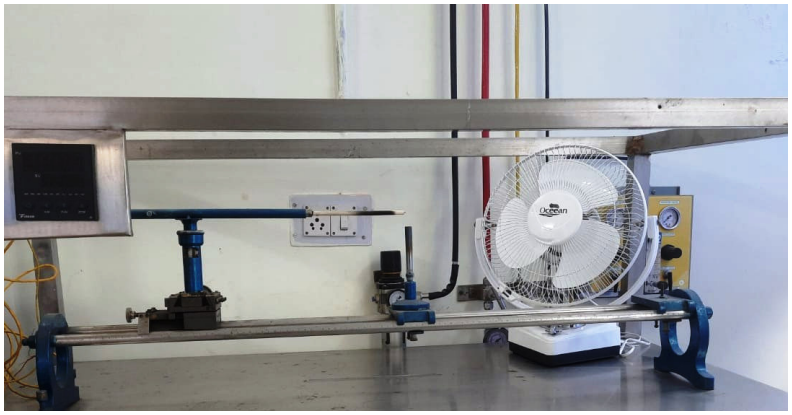
Testing & Evaluation Facility at CSIR-IIP



Experimental facility as per IS 17153

Testing & Evaluation Facility at CSIR-IIP

Combustion Efficiency Test Setup



Draught Resistance Test Setup

Wall, Ceiling Temperature measurement Test Setup

Commercialization

To commercialize the technology, CSIR-IIP organized a "Demonstration cum Technology Transfer Program for the Novel Fuel Efficient Domestic PNG Burner" on 15th of March 2019 at CSIR-IIP. The event focused on dedicating the PNG burner technology to the Nation. It was decided to straightaway issue the technology license on a non-exclusive basis to every interested party. After detailed technical deliberations and laboratory demonstration, the technology licenses were granted to 32 manufacturers on a single day. The total no. of licenses granted till date are 42.

Popularization

Honorable Minister MOPNG Sh. Dharmendra Pradhan in his speech during the occasion of the launch of commencement of work of 10th CGD Bidding Round from Vigyan Bhawan, New Delhi on 26 August 2019, mentioned that the developed PNG burner of CSIR-IIP has the potential to make a great positive impact on the overall CGD sector by Fuel Saving

PIB Release ID: 1583009

Skill Development

An integrated Skill Development Program on PNG Stove for testing Facility, Quality Control and Authentication was organized at CSIR-Indian Institute of Petroleum during 14-15 October 2019. The workshop was attended by 14 participants from 10 different stove manufacturing companies

Recent Development

Creating Future Fuels

(a)

(b)

(a) M/s Print Peal Pack Limited (one of CSIR-IIP licensee) has signed agreement with Goa Natural Gas Limited in the month of January, 2024 for the supply of PNG stoves in Goa.

(b) PNG stove of CSIR-IIP was displayed by Gail Gas Limited (GGL) at the India Energy Week 6-9 February 2024.

CSIR-IIP PNG Burner

Creating Future Fuels

25% more fuel efficient than the in-use retrofitted stoves

Technology transferred to 42 nos. of stove and burner manufacturing companies

Annual fuel saving of Rs. 5,000 million and 1 million tons of CO_2 emission reduction

Meets all the requirements of IS :17153 2019 and gives Thermal Efficiency of >65%

Potential to revive the MSME sector with a market size of Rs. 10,000 million

Indian patent Granted: No.: 461166, dated 20.10.2023

More than 500 installations in last 3 months

Manufactured under the "Make in India" and "Swach Bharat Mission"

Thank You

CSIR-Indian Institute of Petroleum
Dehradun-248008

Fax: 0135-2660202, **Ph:** 0135-2660205

E-mail: director@iip.res.in, **Web:** www.iip.res.in