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Performance Analysis of Burners used in LPG Cooking Stove-A Review

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Abstract: L.P.G is the most convenient and clean fuel for domestic use and is very popular in these days. The LPG stove industry is about 36 years old and is mainly concentrated in the small-scale sector. LPG is an exceptional energy source due to its origin, relative advantages and applications. No wonder LPG is known as The Ideal Fuel for Modern Living. With global availability, environmental benefits, its natural by-product origin, transportation flexibility and diverse application, LPG plays a pivotal role in the transition towards a more secure, sustainable and competitive energy model. Considering the limited fossil fuel resources, energy conservation, environmental issues, increase in the demand on LPG in near future, it is a necessary to explore the ways to further improve the thermal efficiency and the emission characteristics of the existing LPG cooking stoves. In the present work, various works dealt with research in increasing thermal efficiency of stoves using different fuels, and different burners are studied. Various parameters affecting thermal efficiency of a burner are determined.

Keywords: LPG cooking burner, performance Analysis, efficiency

I. INTRODUCTION

A gas burner is a device to generate a flame to heat up products using a gaseous fuel such as acetylene, natural gas or propane. Some burners have an air inlet to mix the fuel gas with air to make a complete combustion. Acetylene is commonly used in combination with oxygen. It has many applications such as cooking, soldering, brazing and welding, the latter using oxygen instead of air for getting a hotter flame which is required for melting steel. For laboratory uses a natural gas fired Bunsen burner is used. For melting metals with melting points of up to 1100 °C such as copper, silver and gold a propane burner with natural drag of air can be used. LPG stove is a relatively simple appliance for direct combustion. Its burner is a premix and multi-holed burning ports type, and operates at atmospheric low-pressure. A typical gas stove consists of gas supply tube, gas tap/valve, gas injector jet, primary air opening(s) or regulator, throat, gas mixing tube/manifold, burner head, burner ports (orifices), pot supports and body frame.

Center for Energy Studies, Institute of Engineering Tribhuvan University, Pulchowk, Lalitpur,Nepal [1] have found out the efficiency of biogas stove. For comparison, efficiency of LPG (Liquefied Petroleum Gas) and kerosene stove (pressure type and wick type) was also studied.

Efficiency of a stove could be categorized as burning efficiency and overall efficiency. Burning efficiency of a stove accounts for the capacity of that stove in terms of combustion of fuel, in other words ability of the stove to change the energy from fuel to heat energy is related with burning efficiency. The ability of the stove to change the energy from fuel into the energy gained by the specimen such as water, rice, milk etc is termed as overall efficiency of the stove. Generally efficiency of stove is indicated by overall efficiency.

Other evidences on calculation of efficiency of different types of stoves were studied for their research. Overall efficiency of stove depends upon different conditions such as temperature, pressure, wind speed, specific heat capacity of the vessel, bottom and overall shape of vessel, weight of vessel, size of vessel and amount of specimen. Thus different tests for efficiency could yield different results of the same stove. Calorific value (MJ/kg or kJ/ Lit) of the fuel is the input energy for stove and they accounted it in course of efficiency measurement.

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Methodology applied by them was as follows [1]-[11]

Overall efficiency = hc * hr

Where,

hc = combustion efficiency

hr = Heat transfer efficiency

Overall efficiency = Percentage of chemical heat that enters the pot.

In their study methodology used was - efficiency of cook stoves was determined by calculating the heat gained by the water subjected for heating and amount of fuel consumed during this process. Heating of water from initial water (subjected to boiling) temperature T|°C to boiling point is termed as High Power Phase (HPP). During this phase water in vessel gains energy from fuel with the help of burning stove and that value of energy is equivalent to energy required to raise the temperature of that mass of water from T|°C to boiling point. In Low Power Phase predetermined weight of water at boiling point was subjected to boil for five minutes and energy gained by this water is calculated by multiplying latent heat of vaporization of water and mass of vaporized water. Fuel consumed during each process is the input energy for these phases. Overall efficiency is calculated by dividing output energy by input energy. In this process they have included the heat gained by vessel in which water was boiled. Heat gained by vessel = Mv * Sv * (Tb - Ti) Joule

Heat gained by water in HPP= Mw * Sw * (Tb - T,) Joule

Heat gained by water in LPP = (Mstesm *Lwboil) Joule

Energy of fuel = (Mfule * Kfuel) Joules

Where-

Mv = Mass of vessel

Sv = Specific heat capacity of vessel

(Tb – T1) = Change in temperature (from Tl to boiling Point)

Mw = Mass of water

Sw = Specific heat capacity of water

Msteam = Mass of evaporated water during LPP

LWboil = Latent heat of boiling of water

Mfuel = Mass of consumed fuel

Kfule = Calorific Values of Fuel

Efficiency (overall) ={MW*SW* (Tb - T,) + (Msteam *Lwboil) + Mv * Sv * (Tb - T,) } /
(Mfule * Kfulel)

Efficiency (overall) = {Heat gained by water in HPP + Heat gained by water in LPP
+Heat gained by vessel} / {Quantity of fuel consumed * unit calorific values of fuel}.

Constants taken for calculation:

- Specific Heat Capacity of Water = 4190 J/kg °C
- Specific Heat Capacity of Aluminium = 125 J/ kg °C
- Calorific value of Kerosene = 42 MJ/kg
- Calorific value of LPG = 44 MJ/kg
- Calorific value of biogas = 22 kJ/Lit

They conclude their work with following observations-

The efficiency of a given stove is not constant. It could vary on the basis of surrounding conditions and quality of fuel used. A high value of efficiency could be obtained under controlled conditions. But in practice this value is normally lower than the value found in the controlled laboratory condition. The efficiency of stove depends upon following conditions:

a. Environmental conditions, such as wind, temperature, pressure

b. Shape, specific heat capacity and weight of vessel.

e. Burner size of stove and size of bottom face of cooking vessel.

d. Energy content of fuel and quality of fuel.

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II CASE STUDIES

1. Walter M. Berry, I. V. Brumbaugh, G. F. Moulton, and G. B. Shawn, in their first part of paper presented the design of gas burners. They developed an atmospheric gas burner. They develop the arrangement of apparatus and method of testing. For their work they studied the theory of flow of gas through different types of orifices, the principles governing the rate of injection of air into the burner, the design of the injecting tube, the rate of consumption of burners of different port areas, and the effect of adjustment of the air shutter. The rate of discharge of gas orifices of different types was found to vary greatly with a variation of the angle of approach and with the length of channel or tube of the orifice. It has been found that for any given burner the ratio between the momentum of the gas stream and the momentum of the stream of the air-gas mixture entering the burner is always a constant, and this relation enables one to calculate readily the effect on the volume of air entrained when the gas pressure, gas rate, or specific gravity of the gas is changed.

For their work they tested performance of burner on various strategies. Various types of burner orifice were designed and optimized. Similarly different models of injection tubes were designed. Orifice position also changed and the optimum injector was selected. A relation between Burner tube and burner ports was used to find out the characteristics of satisfactory burner. With smaller size port, it was possible to turn the gas lower without causing a flash back. The secondary air having a greater cooling effect on the small flames is reducing the velocity of flame propagation.

They found an important co- relation between the area of the throat of the injecting tube and the area of the burner. The results of the tests show that the area of the injector throat should be about 43 per cent of the area of the burner ports. They provided a guideline to choose a burner for any conditions- there has been compiled a series of tables, based on the preceding experimental work and calculations, which show the rate of consumption of various sizes of burners for different pressures and air-gas ratios. Since the rates of consumption of burners without injecting tubes increase with increasing port area, it will be difficult to make up tables that will be generally applicable for the various types of burners. With an injecting tube the rate of consumption of a burner is increased so much that it is necessary to have the pipe larger in proportion to the port area, otherwise the velocity past the first ports is too great to give good results. Burner with simplicity, low cost, and reliability the well adapted for domestic and most of the smaller industrial purposes. If their range is widen, such burners can be operated efficiently and without adjustments, and design them to meet the needs of any particular purpose, it will make gas fuel much more valuable and will broaden its field of application.

2. Obada David Olubiyi has designed constructed and evaluated performance of biogas burner. The work geared towards modification and the improvement of biogas burners and their efficiency. The performance of the stove was evaluated by the process of boiling water. The efficiencies of the stove in water boiling and rice cooking were 21%, and 60% respectively. Also, flue gas analysis was carried out to establish the emissions of the stove. The combustion efficiency of the stove recorded by the flue gas analyzer was 86.9%.

For concerned work, Obada David Olubiyi focuses on design details of Gas flow rate through injector, Injector orifice/jet design, throat design, Burner port design, secondary air supply, flame stabilization, pot supports, and specification of fuel (Biogas). Perfect material selection for different components was next prime important task.

Prime design parameters were-

- Gas inlet pipe should be smooth
- Diameter of the jet (do)
- Length of the mixing pipe (L)
- Number and diameter of flame port holes (dH)
- Height of the burner head. (H)

Design considerations-

- Specific gravity of gas
- Calorific value
- Volume of biogas produced
- Composition of the gas produced
- Gas pressure
- Flame speed (velocity)

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After implementation of different designs parameters, a burner is fabricated, and evaluated for performance. Flue gas analysis also performed. Following results were obtained -

- The potential of this stove can be maximized by improving the air/gas regulating mechanism.

- The percentage of O2, CO2 and excess air were constant for the flue gas analysis done on the three (3) burners tested. This was because the machine worked on some preset values inputted during calibration for different kind of fuel.

Further work will be to-

1. Affect the air/gas regulating mechanism by improving the method of moving the injector into and out of the air/gas mixing chamber

2. Design and construct a 2-flame burner deriving from the experience of the single-flame burner evaluated in this research.

3. Apinunt Namkhat and Sumrerng Jugjai investigated the effects of changes in the combustion air temperature on the primary aeration and flame structure for self-aspirating burners. They performed studies for with and without preheat case of combustion air. They observed that the level of primary air entrainment is increased with increasing the heat input. The preheated case gives a lower primary aeration than the without preheat case, because the preheating effect will make the fluid in the mixing tube has more viscosity. A yellow tip flame also occurs with increasing the preheated air temperature due to decreased primary aeration. It will be helpful in designing a high-performance burner in the future.

For their work LPG is used as a fuel in the experiment, the oxygen sensor was used to measure oxygen concentration with an accuracy of about 0.05%. An uncertainty analysis was carried out with the method proposed by Kline and McClintock, Using a 95% confidence level, the maximum and minimum uncertainties in the presented primary aeration were found to be 3.3% relative and 1.6% relative, respectively.

A set up was installed for primary aeration measurement using the oxygen sensor which is applied for both with and without preheat cases. It was composed of a self-aspirating burner.

For the preheat case, a similar experiment was performed using the same procedure as described for the without preheat case, but with a primary air preheat. They select four preheated air temperatures (T_{pre}) for the experiments (50 ^{o}C, 100 ^{o}C, 200 ^{o}C, and 300 ^{o}C). The static pressure was measured by the water manometer. Meanwhile, the flame images are also captured with a digital camera.

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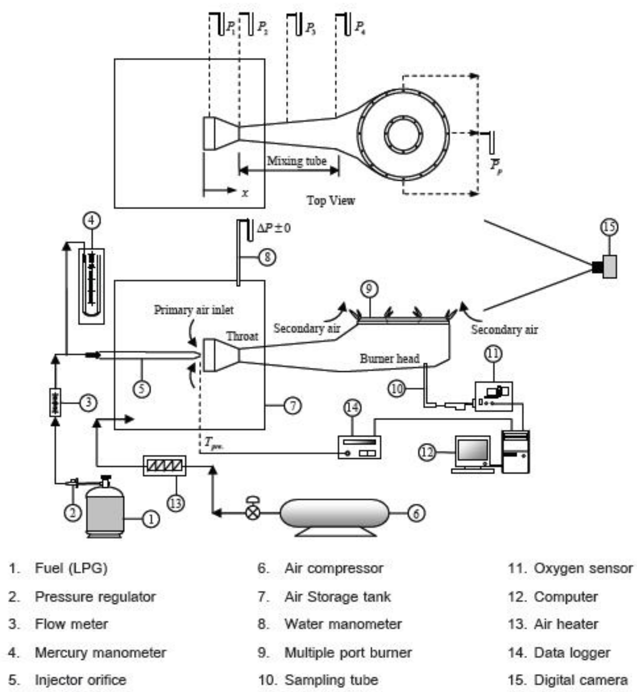

Fig 1. Schematic diagram of primary aeration experiment [2]

Apinunt Namkhat and Sumrerng Jugjai got following results- the primary aeration in both cases rapidly increases at the early stage with an increasing heat input. After that, the primary aeration is stable and no longer dependent on the heat input, due to limitations of mixing tube and burner port sizes. The primary aeration decreases with an increasing preheated air temperature.

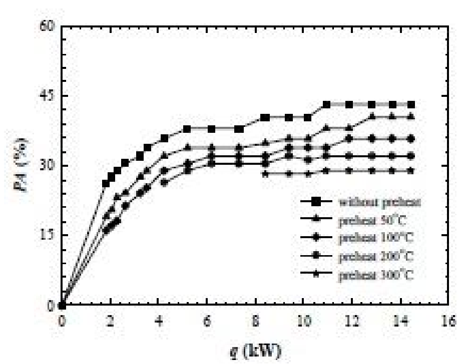

Fig 2. Typical primary aeration of a self-aspirating burner [2]

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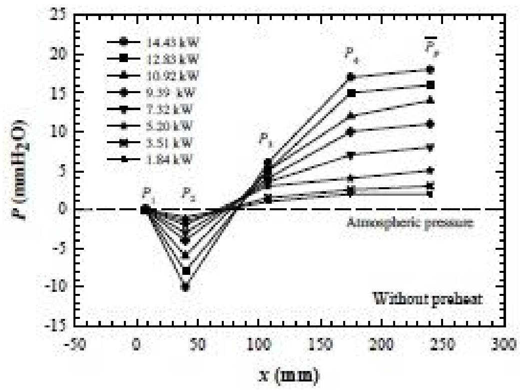

Fig 3. Effecting of heat input on pressure drop along a self-aspirating burner [2]

The preheated air temperature of T= 300 ^{o}C gives about a 14 percentage point (33% relative) lower value than that of the without preheat case, because the preheating effect causes expansion of the mixture and an increase in its viscosity.

The pressure distribution for the preheat case is greater than that of the without preheat case. The pressure distribution increases with the preheated air temperature

For Flames-

The flame image of a self-aspirating burner in the open environment for the without preheat case-, The flame structure of a partially aerated burner has two distinct regions: the inner cone flames and the outer cone flames. The inner cone flames are the rich premixed flames burning with the entrained primary air, while the outer cone flames are the non-premixed flames due to the combustion of the unburnt fuel and intermediate species with the secondary air. It was observed that a yellow tip flame occurs in the inner cone flames as heat input decreases. On the other hand, when further increasing heat input, the inner cone flames are greenish-blue in colour showing the abundance of CH and C_2 in the flames. However, the yellow tip flame appears in the outer cone flames, because the mainly secondary air cannot entrain from the surrounding above the burner plane. Flame appearance and flame stability are affected by thermal input (flow rate of fuel) and primary aeration. It was found that the increase of thermal input leads to the increase of flame height, because of the high velocity of the gas mixture.

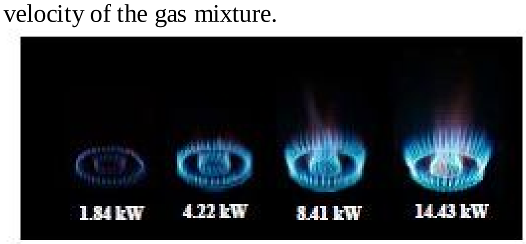

Fig 4. Effecting of heat input on flame structure for without preheats case [2]

Flame images obtained with the different preheated air temperatures- yellow tip flame occurs with increasing the preheated air temperature due to decreased primary aeration.

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The high preheated air temperature is responsible for low primary aeration and an increase in the burning velocity. Thus, the flame height found is almost constant irrespective of the temperature of preheated primary air.

Fig 5. Effecting of primary air preheat on flame structure at q =8.41 kW [2]

They conclude their work with – The Primary Aeration level in both with and without preheat cases rapidly increases at the early stage with increasing heat input. After that, it is stable and no longer dependent, due to limitations of mixing tube and burner port sizes. Due to decreased primary aeration, a yellow tip flame occurs with increasing the preheated air temperature.

CO emissions level increases, due to incomplete combustion However, the flame height is almost constant due to increased burning velocity. They recommend, in order to design a high-performance burner in the future, the preheating effect can be taken into consideration in designing the mixing tube so as to obtain an accurate primary aeration.

4. V.K. Pantangi, Subhash C. Mishra, P. Muthukumar, Rajesh Reddy work on the performance tests of a PRB (porous radiant burner) used for LPG (liquefied petroleum gas) domestic cooking stoves. Combustion in porous medium has attracted more attention due to its clean and high combustion efficiency. For getting these advantages the burner was constructed with two-layer porous media. The combustion zone was made up of silicon carbide, and alumina balls were used to form the preheating zone. For a given burner diameter, the performances of the burner, in terms of thermal efficiency and emission characteristics, were analyzed for different equivalence ratios and thermal loads (wattages). The water boiling test as prescribed in the BIS (Bureau of Indian Standard): 4246:2002 was used to calculate the thermal efficiency of both the conventional LPG cooking stoves and the PRB. The maximum thermal efficiency of the LPG cooking stoves with a PRB was found to be 68% which is 3% higher than that of the maximum thermal efficiency of the conventional domestic LPG cooking stoves. The axial temperature distribution in the burner showed that the reaction zone was close to the interface of the two zones and at a higher thermal load, it shifted towards the downstream. The surface temperature of the PRB was found to be uniform.

The CZ (combustion zone) of the two-layer PRB was made of SiC (silicon carbide) porous matrix. Al2O3 (Alumina) balls of 5 mm diameter form the PZ (preheating zone). The porosity of PRB was 90% and its thickness varies from 1.5 cm to 2.0 cm. The burner casing was fabricated using alumina powder and sodium silicate binder. To sustain high thermal stresses, casing was sintered at high temperatures. The PRB consists of a combustion zone, a preheating zone, a wire mesh to support the preheating zone, a burner casing and a mixing tube made up of Teflon. The experiments were performed with different diameters and thicknesses of the combustion zone. 5 different types of burners were used in this investigation. These burners are named as B6, B7, B8, B9, and B10. The experimental set-up used for testing the performance of PRBs .The fuel-flow and air-flow rates were monitored using the rotameters with control valves. The compressed air and the LPG at a pressure of 3.0 kN/m2 were taken through their respective rotameters to the mixing pipe. The water boiling test as per the guidelines of the BIS: 4246:2002 was employed to measure the thermal efficiency of the LPG cooking stoves. The distance between the burner surface and the bottom of the pan, as per BIS was kept at 5.0 cm.

The CO and NOX emissions were measured using the TESTO 350 XL portable flue gas analyzer. The sampling was done as suggested in the BIS: 4246:2002.

The maximum thermal efficiency in each case has been observed at different equivalence ratios, and this is for the reason that for different burners, for the flameless condition, the air requirement was different. For a given burner at a given wattage, the thermal efficiency is higher at lower equivalence ratio and found to decrease with increase in equivalence ratio. For example, for B6 burner at 1.3 kW, efficiency decreases from 63% to 50%, when the equivalence ratio increases from 0.41 to 0.51.

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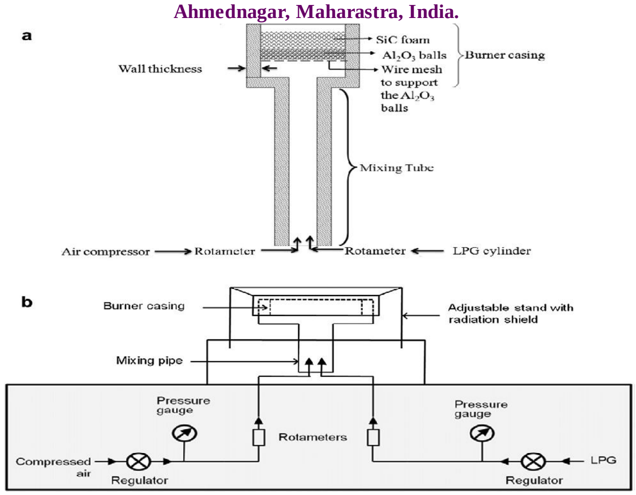

Fig 6. Schematics of the (a) porous radiant burner and (b) the experimental set-up.[5]

For the two-layered PRB, the investigation was made for five different combinations in terms of thicknesses and diameters of the combustion zone made of SiC. Axial and radial temperature istributions of the burner were measured for different wattages and equivalence ratios. For all the burners thermal efficiencies and CO and NOX emissions were also obtained. The axial temperature measurement revealed that at higher wattages, the reaction zone shifted downstream of the burner. The radial temperature was found to be more uniform for higher wattages, which can be a desirable feature of any burner. The maximum thermal efficiency of the B8 burner was about 68%, which is 3% higher than the maximum thermal efficiency of the conventional LPG domestic cooking stoves. The thermal efficiency of the PRBs was found to increase from 62% for B6 to 68% for B8 burner. The maximum thermal efficiencies of B8 and B9 burners were found to be almost the same (68%). However, the maximum thermal efficiency of B10 burner was found to decrease due to the higher radiation heat loss. The CO and NOX emissions of the PRBs were in the range of 25e350 mg/m3 and 12e25 mg/m3, which are much lower than the corresponding. values (CO: 400e1050 mg/m3 and NOX: 162e216 mg/m3) for the conventional LPG domestic cooking stoves.

5. N. K. Mishra, P. Muthukumar, Subhash C. Mishra, implements the concept of Porous Medium Combustion (PMC) in to porous radiant burner (PRB). In PMC, the combustion of fuel and air mixture takes place inside a matrix of open cavities in the presence of an inert solid surface. The porous matrix has high thermal conductivity and high emissivity as heat transfer takes place through conduction and radiation. They conduct performance tests on PRB used for medium - scale cooking applications of capacity 5-10 kW was presented.

The PRB chosen for the study was SiC-based porous burner. Liquefied petroleum gas (LPG) was used as a fuel. Effects of different heat inputs in the range of 5 - 10 kW on the thermal efficiency and emission levels of PRB are investigated. For the conventional LPG burner of 5-10 kW capacity, the measured value of thermal efficiencies is in the range of 30-40%, and the CO and NOx were in the range of 350-1145 ppm and 40 - 109 ppm, respectively. These emissions levels were well above the world health organization standards. Within range of parameters tested, the SiC-based PRB yields the maximum thermal efficiency of about 50%, which is about 25 % higher than the conventional stoves.

In conventional combustion devices are free flame, with convection as the only mode of heat transfer. Hence conventional combustion devices less efficient and result in increased CO and NOx emissions due to poor the poor heat transport. The LPG cooking gas burner is one such device that goes well with this category of high emission levels and low thermal efficiency. To overcome the difficulties of the free flame combustion, another means of combustion was discovered known as porous medium combustion (PMC). PMC offers high power density, high power dynamic range and very low NO and CO emissions, also the high levels of heat capacity, conductivity and emissivity of the solid matrix, compared to a conventional combustion devices.

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The fuel and air flow rates were monitored using the coriolis flow meters with suitable valves. Air–fuel mixture moves to the burner through a mixing tube made of Teflon. Adjustable stand has been attached with a radiation shield. The PRB used for the work was based on two-layered PMC, a combustion zone and a preheating zone. Combustion zone was formed with high porosity (90%), highly radiating SiC porous matrix, and the preheating zone consists of low porosity (40%) ceramic matrix of 120 mm diameter. Inside the burner casing, a wire mesh is provided to support the ceramic block. The burner casing was fabricated at IIT Guwahati using alumina powder and sodium silicate binder.

Thermal efficiencies of the LPG cooking stoves were estimated by conducting the water boiling test as per the guidelines described in Bureau of Indian Standard (BIS):4246:2002. To compare the thermal efficiencies of conventional burners with PRB, a market survey was carried out to get the various types of burners used in conventional commercial LPG cooking stoves. The efficiencies and emissions of PRB and conventional burners were calculated using the same procedure. The CO and NOx emissions were measured using TESTO 350 XL portable flue gas analyzer. The sampling was done as suggested in the BIS: 4246:2002

Fig 7. Commercial burners used for performance test [6]

Thermal efficiency was measured for conventional burners at different thermal loads and it was found in the range of 30-40%.Whereas thermal efficiency for PRB was found in the range of 40-50%. For the chosen configuration of the PRB, with increase in the thermal load, the observed trend of lower efficiency was attributed to the fuel rich mixture and increased heat loss.

The CO and NOx emissions from the conventional burner and the PRB were tested for exhaust gas analysis for different thermal loads. At all thermal loads, both CO and NOx emissions were found lower for the PRB.

It was concluded that thermal efficiencies of the PRB gradually decreased with increase in power intensity. PRB with 5 kW thermal loads the maximum thermal efficiency of about 50%, which was about 25% higher than the efficiency of the conventional burner. At the thermal load of 10 kW, the PRB gives the maximum improvement in thermal efficiency of about 34.3 %. The measured emissions of CO and NOx were much lower than the conventional commercial burner.

6. Mohd. Yunus Khan1 and Anupriya Saxena, focused their work on finding the effects on using different design burner heads on the performance of LPG cooking stove. Burners of different material were used to study the effects of burner material on LPG stove performance. It was experimentally found out that thermal efficiency of stove using flat and flower face brass burners were higher as compared to regular cast iron burner.

The burner head was removed and replaced by different design. Different burner head designs used in this work. Thermal efficiency was found out as per the BIS. It is observed that thermal efficiency of LPG stove improves by using flat and flower faced burners. When flower face burner was used, thermal efficiency of LPG stove was found to improve. The thermal efficiency of flat face brass burner was found to be maximum of 58%.

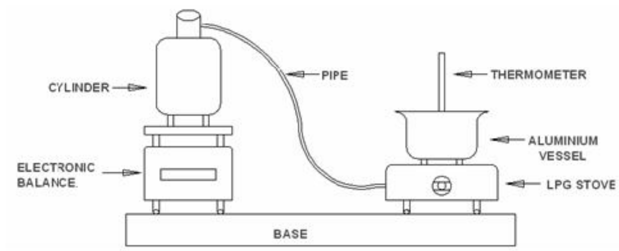

Fig 8. Experimental setup [7]-[11]

The thermal efficiency of LPG stove for regular cast iron burner was found to be 48%. When flat and flower face burners were used, thermal efficiency of LPG stove improved. When flat face brass burner was used maximum thermal efficiency of 58% was achieved. While thermal efficiency of 50% was observed when face brass flower burner was used. Further, it was experimentally found out that thermal efficiency of LPG stove using regular brass burner was 4% higher as compared to regular cast iron burner. The technique of replaced of burner head is simple and safe. It can be easily implemented in domestic LPG stove for fuel conservation

7. Catharine Tierney, Susie Wood, Andrew T. Harris and David F. Fletcher, implement convective and radioactive heat transfer models to the commercial computational fluid dynamics (CFD) code ANSYS CFX, they describe the interaction between the porous solid and the fluid. In addition a relatively detailed skeletal chemistry mechanism was incorporated and a stiff chemistry solver was used to provide an accurate assessment of the combustion behavior. The porous medium produces improved efficiencies, reduced pollutant emissions, an enlarged stable operating power range and, importantly, the ability to operate at concentrations near or below the lower flammability limit.

They also developed the numerical model, added gas mixture properties to this model and apply conductive, convective and radiant transfer within porous domain.

Fixed flux boundary conditions were applied for an analytical validation of the heat transfer equations. In addition, the validity of the chemical mechanism in the numerical model was confirmed using CHEMKIN (Reaction Design, 2006). This validation was accomplished by imposing a CFD fluid temperature output profile onto a plug flow reactor in CHEMKIN under the same inlet conditions. The CFD profile was obtained without gas transport in accordance with the plug flow reactor conditions. Comparisons of the concentration profiles from CHEMKIN with those from the CFD verified the correct implementation of the chemical mechanism within the CFD model.

The model results indicated that the energy balance of the system determined the combustion performance and flame location. This balance was directly influenced by heat recirculation within the solid matrix and by solid to fluid convective transport.

8.Pankaj P. Gohil and Salim A. Channiwala, Perform the analysis of conventional LPG cooking stove, found 66.27% thermal efficiency. Emission test and water boiling test were conducted according to IS 4246:2002.

III.CONCLUSION

Various works related with performance and efficiency of the conventional cooking stoves was studied. Some experiments were based on other fuels such as kerosene and biogas. But basic objective for the research was found to be same. In all the case studies, a common factor is observed which affect the performance of a stove severely; it is a burner of any stove. Hence we have to improve the efficiency of a stove, we must focus on burner specifications, designs and its materials.

1. Air preheating effect can be taken into account for better efficient burners.
2. If Porous Medium is constructed in a burner, its emission of CO and NO_x are found to be lowered compared to conventional burners. Also the thermal efficiency has been increased.
3. Burner material and construction also affects the performance of a stove. Brass burners found more efficient than cast iron burner. Similarly flat faced burner is more efficient than face flower.
4. The results show that the area of the injector throat should be about 43 per cent of the area of the burner ports.

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