# DEVELOPMENT OF ENERGY SAVING METHOD IN GAS HEATING USED FOR PRESSURE COOKER ON A GAS STOVE BY REDUCTION OF HEAT LOSSES

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***ABSTRACT***

*This paper aims to present an experimental data which clearly establishes the possible energy and fuel savings in the conventional LPG stove heating abundantly used in cooking of foods. The heat losses occurring in pressure cooking by LPG gas stove configuration are measured. Few lay moulded and suitably configured insulation devices are used to reduce the heat losses. Using these designed insulating devices, the reductions in heat losses are measured. The results and analysis carried out indicate energy savings of ~5 to 10%. Taking into account the large quantity of LPG gas consumed everyday (~ 10 to 20 tonnes per day in Karnataka alone) this can lead to enormous savings in fossil fuel consumptions, as the fossil fuel resources are getting depleted gradually.*

## I. INTRODUCTION

Gaseous fuel such as Indane (LPG) gas is used abundantly for gas stoves in India in cooking (both for domestic and commercial establishments). Even a small percentage saving in consumption would lead to large fuel economy. LPG gas is a mixture of Butane and propane and has a calorific value of ~ 94 $MJ/M^3$

The gas stoves presently being used for cooking and pressure cooker used do not take care of certain heat losses that occur. This study was conducted as a part of Graduate level students Project work at Sapthagiri college of Engineering, Bangalore, Karnataka state.

Fig. 1

fig.2

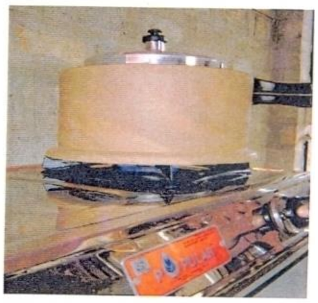


fig.3

**Fig 1** shows an uncoated cooker in heating, **Fig 2** shows copper bottom cooker in heating **Fig 3** shows insulation mould around cooker in heating.

1.1 Organization of the paper

Section 2 of this paper describes the experimental setup while the assumptions are enumerated in Section 3. The principles of measurements, instruments used and methodology of measurements are enumerated in Section 4. The observations are listed in Section 5. Detailed calculations are shown in Section 6. Conclusions are drawn in Section 7 while Section 8 lists out the possible future work. Section 9 gives Appendix containing tabulated results, figures and other observations.

## II. THE STUDY AND EXPERIMENTAL SETUP

This study was conducted to estimate practically the heat losses occurring in a gas stove heating with pressure cooker and by use of insulating devices designed and manufactured using clay moulded ring and placed around the vessel being heated. The experimental setup consists of standard LPG gas stove setup with a gas regulator and Al alloy Pressure cooker of 6 litres capacity as shown in the figure 1,2,3. Thermocouple/RTD type based temperature measuring devices are used to measure temperatures at different zones during the experiment. The calorific value of LPG gas determined using Boy's gas calorimeter in the Energy conversion Lab and verified. The experiments are done as described below:

2.1 A known exactly weighed amount of water is taken inside the pressure cooker and the cooker is placed on the gas stove closed with the weight of cooker in the nozzle and at an adjusted throttle condition gas (gas flow rate 3 lpm) is allowed to flow and burn. The time taken for raising the pressure till the steam is ejected out of cooker nozzle outlet (1$^{st}$ whizzle) is recorded and the gas flow is measured (adjusted to 3 litres per Minute)

**Fig. 4** Coal being burnt in LPG Gas Stove

**Fig.5** LPG Gas Stove With Blue Flame

2.2 Another 6 litres cooker with copper coated bottom is also filled with same amount of water inside the cooker and closed by weight of cooker in the nozzle .Same conditions of gas flow(3 lpm), weght and again the time taken to raise steam ($1^{st}$ whizzle) is recorded

2.3 $3^{rd}$ experiment(Fig.3) is done exactly under same conditions of water taken inside cooker, weight of cooker, gas flow rate etc. but a mud moulded ring placed around the cooker vessel as shown in the figure 3 and the time taken to raise steam ($1^{st}$ whizzle) is again recorded.

2.4 Fourth experiment is done at the same conditions of gas flow, cooker weight, water taken inside cooker etc. but the cooker used is the copper coated bottom pressure cooker and clay moulded insulation ring placed around the cooker to prevent heat losses.

In each of the above 4 experiments, the temperatures at the surface of cooker at top, sides are recorded The temperature profiles with Aluminium alloy cooker alone are also measured vertically and horizontally till room temperatures are reached. The 4 experimental setups are as shown in the figures 1, 2 and 3.

**Fig.6** Rtd With Cable

**Fig.7** Rtd's

## III. ASSUMPTIONS

1. The two pressure cookers Prestige company make are of same capacity and are identical (both 6 litres capacities) in masses, wall thicknesses and same materials and so same properties.
2. The pressure cooker with copper coated bottom is coated with 300 microns thickness which only changes the faster heat transfer from gas to vessel and rest of the conditions are exactly same.
3. The Thermal conductivity of Aluminium alloy is taken from standard tables as per supplier and 150 W/m. Is the value assumed (for Aluminium alloy)

4 The heat flow is only upwards from the burner (no heat loss towards the bottom of the burner)

4 The heat transfer from gas burning is from bottom of the vessel by conduction, by convection and radiation from vertical side surfaces.

5 The calorific value of LPG gas is assumed as 94 $MJ/M^3$

6 The Thermal conductivity of Aluminium alloy material of pressure cooker =150 W/M.k

7 Properties of hot flue gas at fluegas film temperature $60^0$c :Density=1.029 $kg/m^3$
$105^0$c = 1.101 $kg/m^3$

- Kinematic viscosity =20.02x$10^{-6}$ $m^2$/sec($105^0$c).;thermal diffusivity = 29.6x $10^{-6}$ $m^2$/sec($105^0$c).
- = 17.7 x$10^{-6}$ $m^2$/sec($60^0$c) =25.35x $10^{-6}$ $m^2$/sec($60^0$c)
- Specific heat = 1.009x$10^3$j/kg.k; Stefan Boltzman constant = 5.67x$10^{-8}$ w/m.$k^4$
- = 1.005x$10^3$j/kg.k; thermal conductivity= 0.028 and 0.03 w/m.k

## IV. PRINCIPLE AND METHODOLOGY OF MEASUREMENTS

- It is observed that the burning hot gases from burner transfer heat to the vessel thro' bottom surface of cooker and then there are convective currents flow along the vertical walls of the vessel and flow upwards by exchanging heat to the vessel and then escape from top lid area of the pressure cooker. Heat transfer from burning gas to pressure cooker are by (i) conduction and radiation at bottom surface and by conduction, convection and radiation through side vertical surfaces.
- The gas flow is measured by gas flow meter in Boy's gas calorimeter
- Heat released by gas is estimated by product of gas flow rate and c.v. of gas
- The heat losses by conduction, convection, radiation are measured based on observations of wall temperatures, cooker bottom temperature, dimensions of walls of cooker, air temperatures, thermal conductivity of cooker material etc.as shown in detail below:

## V. OBSERVATIONS

- Air temperature = $35^0$ c
- Temperature of bottom surface = 300 c
- Temperature of side wall of Al.alloy pressure cooker = 105 c
- Inside radius of Al.alloy pressure cooker = 87 mm= 0.087m
- Outside radius of Al.alloy pressure cooker = 90mm = 0.09 m
- Total length of Al.alloy pressure cooker = 142 mm=0.142m
- Thickness of walls of Al.alloy pressure cooker = 6mm = 0.006 m
- Time taken to raise steam pressure($1^{st}$ whistle) with Al.alloy pressure cooker without any coating = 6 minutes and 14 seconds
- Time taken to raise steam pressure($1^{st}$ whistle) with Al.alloy pressure cooker with coating = 5 minutes and 54 seconds
- Time taken to raise steam pressure($1^{st}$ whistle) with Al.alloy pressure cooker without any coating but with clay moulded insulation ring = 5 minutes and 51 seconds
- Time taken to raise steam pressure($1^{st}$ whistle) with Al.alloy pressure cooker with coating but with clay moulded insulation ring = 5 minutes and 26 seconds

## VI. CALCULATIONS

**Heat losses = Heat loss by convection from side walls+Heat loss by convection from top surface+Heat loss by radiation from side walls** and top surface

The 4 experiments done as per para 2.1,2.2,2.3 and 2.4.The calculations are similar to all these 4 cases however one typical calculations are shown below for case 2.1 that is when the Al.alloy pressure cooker (without any coating) is heated:

1.1 Determination of heat loss by convection from side walls:

$\beta = 1/\theta = 1/(273+70) = 2.91\text{x}10^{-3}\ k^{-1}$

$G_{R}$ = Greshoff no. = $g\ \beta L^3(T3\text{-}T_{air})/\upsilon^2 = 9.81\text{x}2.91\text{xx}(0.142)^3\text{x}9118\text{-}35)/(20.51\text{X}10^{-6})^2$

$= 15.55\text{X}10^6$

For free convection, $N_u$ = nusselt no.=$0.6(G_R\text{x}P_R)^{0.2} = 0.6(15.55\text{x}10^6\text{x } 0.7)^{0.2} = 15.3$ w/$m^2$ k

$H = N_u \text{ x } K/L = 15.3 \text{ x } 0.03/0.142 = 3.12$ w/$m^2$.k

Total heat liberated by gas = $\text{vxc}_v$ = 3 lpmx94 MJ/$m^3$ = 4700 watts

Heat conducted away from top surface = k.A.dt/dx = 150xЛx0.087x(105-102)/0.006 watts
= 1782.5 watts

Heat conducted away thro' vertical surfaces: Area convecting heat = Лx0.18x0.142 = 0.0802 $m^2$
Q = hAdt= 3.12x0.0802x(105-35) = 17.52 watt

Heat convected from top surface = Q = hAdt =3.12x0.0254x(105-35) = 5.55 watts

Total heat loss by hollow cylindrical surfaces = 5.55+17.52 = 23.07 watts

$Q = F.\sigma.A(t_s^4 - t_a^4)$= 1x5.67x10 x 0.0254($(105+273)^4$-$(273+35)^4$) = 16.47 watts

Total heat by radiation = Q3 = 65.36+16.47 = 81.83 watts
Heat loss reduced by insulated ring = 1887.4-1238.5= 648.9 watts
Energy saved = 648.9watts out of 4700 watts = 648.9/4700= 13.8%
Time saved in fuel consumption = (374-326)/374 = 12.83%

## VII. CONCLUSIONS

- It was observed that there is an established convective fluegas flow upwards along the side walls of the vessel being heated as shown in the fig.3
- The heat losses by radiations are much less compared to conduction and convective losses
- The bottom copper coated pressure cooker only helps in faster heat transfer from burner to the vessel and no effect on heat losses.
- The clay moulded ring being an insulator prevents heat losses by conduction and convection thus saving heat energy to an extent of ~ 5% to 15% of total heat liberated by gas. This was observed in both normal Al. alloy pressure cooker as well as bottom copper coated cooker

## VIII. FURTHER WORKS

- Due to time, budget constraints in getting the project works got done by graduate level students more elaborate and extensive experiments could not be done. More savings in energy can be seen with better insulating moulds other than clay(chosen as it was cheap) such as asbestos, ceramic, fireclay etc. Also different configured moulds can be tried for optimization of heat energy savings.
- The insulation integral coated Pressure cooker lids can be more effective in avoiding heat losses by conduction from top lid.

## REFERENCES

[1]. Heat transfer, a practical approach, Yunus.A. Cengel Tata McGraw Hill.
[2]. Principles of heat transfer , Kreith Thgomas Learning 2001` and son's.
[3]. Fundamentals of heat and mass transfer , Frenk P. Incropera and David P. Dewitt.
[4]. Heat Transfer .,P.K. Nag Tata Mc Graw Hill 2002.
[5]. N.L. Panwar, , N.S. Rathore, "Design and performance evaluation of a 5 kW producer gas stove", Biomass and Bioenergy Volume 32, Issue 12, December 2008, Pages 1349–1352.
[6]. J.O. Jaber, Q.M. Jaber, S.A. Sawalha, M.S. Mohsen, "Evaluation of conventional and renewable energy sources for space heating in the household sector", Renewable and Sustainable Energy Reviews Volume 12, Issue 1, January 2008, Pages 278–289.
[7]. Sumrerng Jugjai, , Natthawut Rungsimuntuchart, "High efficiency heat-recirculating domestic gas burners", Experimental Thermal and Fluid Science Volume 26, Issue 5, July 2002, Pages 581–592.
[8]. S. Jugjai,S. Tia,W. Trewetasksorn, "Thermal efficiency improvement of an LPG gas cooker by a swirling central flame", International Journal of Energy Research Volume 25, Issue 8, Article first published online: 29 May 2001.
[9]. H.S. Zhen, C.W. Leung, T.T. Wong, Improvement of domestic cooking flames by utilizing swirling flows, Fuel, 2014, 119, 153.
[10]. V.K. Pantangi, Subhash C. Mishra, P. Muthukumar, Rajesh Reddy, Studies on porous radiant burners for LPG (liquefied petroleum gas) cooking applications, Energy, 2011, 36, 10, 6074.
[11]. Dilip K. De , Nathaniel Muwa Shawhatsu, Narendra Nath De, Mathias Ikechukwu Ajaeroh, "Energy-efficient cooking methods", Energy Efficiency February 2013, Volume 6, Issue 1, pp 163-175.
[12]. Experimental study and performance evaluation of various cook stove models based on energy and exergy analysis Tyagi, K. S. · Pandey, K. A. · Sahu, S., et al. in Journal of Thermal Analysis and Calorimetry (2012)
[13]. Honkalaskar, H Vijay, Bhandarkar, V Upendra, Sohoni Milind, "Development of a fuel efficient cookstove through a participatory bottom-up approach in Energy, Sustainability and Society (2013)
[14]. Panwar, N. L., "Performance Evaluation of Developed Domestic Cook Stove with Jatropha Shell" , Waste and Biomass Valorization (2010).

[15]. Nordica MacCarty , Dean Still , Damon Ogle, "Fuel use and emissions performance of fifty cooking stoves in the laboratory and related benchmarks of performance", Energy for Sustainable Development Volume 14, Issue 3, September 2010, Pages 161–171

## APPENDIX

**OBSERVATIONS( Properties at film temperature from tables)**

Table-1

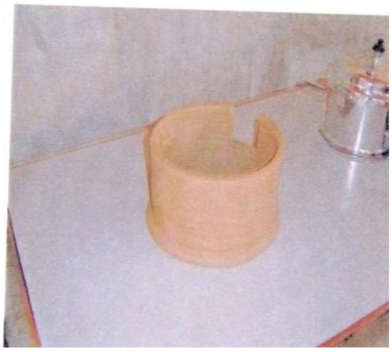
| s.no. | parameter | case 1 | case 2 | case 3 | case 4 |
|---|---|---|---|---|---|
| 1 | Surface temp.(t ) | 105 | 105 | 60 | 60 |
| 2 | Dynamic viscosity | 20.59 | 20.5x10 | 19.48x10 | 19.48x10 |
| 3 | Prandtl no. | 0.7 | 0.7 | 0.668 | 0.608 |
| 4 | Temp. of bottom Surface | 300 | 315 | 300 | 300 |
| 5 | Temp. of side Wall | 105 | 105 | 144 | 144 |
| 6 | Temp. of Top surface | 102 | 102 | 103 | 103 |

**TABLE-2 TABULATION OF RESULTS:**

| Parameter | Al. alloy pressure Cooker without Any coating | Al.alloy pressure Cooker with Copper coated bottom | Al.alloy pressure Cooker without Coating but vessel Closed by clay Moulded ring | Al.alloy pressure Cooker with copper coated bottom & Closed by clay Moulded ring |
|---|---|---|---|---|
| Time taken to raise steam | 6min14sec | 5min54sec | 5min51sec | 5min26sec |
| Rate of total heat produced watts | 4700 | 4700 | 4700 | 4700 |
| Total heat absorbed watts | 1.8MJ | 1.66MJ | 1.65MJ | 1.53MJ |
| Heat lost by Conduction from top surface watts | 1782.5 | 1782.5 | 1188.3 | 1188.3 |
| Heat lost by convection from vertical surfaces watts | 23.07 | 27.27 | 12.88 | 12.88 |
| Heat lost by radiation from vertical surface & top surfaces watts<br>Total heat loss watts | 81.83<br>1887.4 | 81.83<br>1891.6 | 37.29<br>1238.5 | 37.29<br>1238.5 |
| % time saved | ------------ | 5.3(nil) | 6.1(13.8) | 9.1(13.8) |
| Heat saved in each case Kilojoules | ------------ | 94 | 108 | 226 |

*Casing used as a ducting*

*for flue gas, made of clay*



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P. Raghuthama Rao is a graduate of Sri Venkateswara University, Tirupati. Studied at Government College of Engineering, Anantapur (currently JNTU, Anantapur) and pursued postgraduate from IIT Kanpur. After that he worked in Indian Space Research Organisation, Govt. of India and superannuated after 35 years of service. Presently he is a Professor at Sapthagiri College of Engineering in the Mechanical Engineering Department, Bangalore.