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"Experimental Investigation on Pressure Stove with Different Blends of Fuel"

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Abstract: *As a renewable, sustainable and alternative fuel for cooking stove instead of kerosene has been fueled to study its effects on stove performance by some modification done in stove the purpose of modification is to burn the maximum amount of fuel. But these studies have been rarely review to favour understanding and popularization for biofuel so far. From this report the effect of bio-fuel on stove efficiency, flame intensity, durability and the corresponding effect factors are surveyed in details. While for some "improved" stove fuel combinations, the increase in flame intensity is studied. Kerosene is most popular domestic fuel in rural areas of the country. Kerosene is meant to be used as cooking, lighting or heating fuel that is heavily subsidized so it can be purchase more easily by india's poor. However, with ever increasing cost of kerosene and huge subsidies by the government Kerosene is fast disappearing from rural households. In this experiment, horizontal type kerosene pressure stove was modified to burn high percentage of cottonseed oil blends with kerosene. In normal horizontal pressure stove the copper coil is incorporated to absorb the heat radiated through burner to heat up the blend to control its viscosity. The heat which is utilized to heat up the blend is the waste heat which radiated through burner to atmosphere.*

Keywords: *Alternative Fuel, Bio-Fuel, Heat, Kerosene, Pressure Stove, Renewable.*

I. Introduction

The brevity of fossil fuel reserves and accelerating environmental pollution has spurred a continuous search for sustainable and eco-friendly alternative fuels. The increasing industrialization, the depletion of natural fossil fuel reserves and the motorization of the techno savvy world have led to a steep rise in the demand for petroleum-based fuel. These fuels are obtained from the limited natural fossil fuel reserves. However, these finite reserves are concentrated in certain region of the world, and would soon get exhausted. In view of the above problems, the search for alternative fuel has become extensively important. These alternative fuels should be renewable and eco-friendly. Such energy sources are clean sources of energy that have a much lower environmental impact than conventional energy sources. Wood is still the main energy source in rural areas of tropical and sub-tropical countries. An increase in the consumption of wood for cooking purposes results in the cutting of trees, creating severe ecological, economical and sociological problems. Usage of wood as a fuel leads to increased pollution of the atmosphere. In this context, plant oils are a promising alternative energy source that can be used with minimum ecological damage. An agricultural country like India can have a technology that fully utilizes plant oil, thus reducing the dependence on foreign exchange used for importing petroleum products. The present work uses 'used-vegetable' oil as a fuel in a modified stove. In all agriculture-based developing countries, biomass finds extensive use as fuel for cooking and other household activities. The stoves being used at present have very low efficiency in the order of only 5–9%. Also they cause emission of greenhouse gases like CO, NO_x, etc. Constant exposure to such pollutants frequently causes severe health problems such as respiratory disorders, lung disease, tuberculosis, lung cancer, and so on. Women and children are in particular affected by these gases. In most developing countries the exposure is 20 times more than the guideline values given for these gases. Because of the above, it is necessary to replace biomass with a suitable fuel and with a stove having better combustion efficiency.

A number of researchers are developing alternative stoves to improve the efficiency with different fuels. There are two types of stoves: the wick stove and the high-pressure pump stove. Since the thermal efficiency of wick stoves is very low when compared with the high-pressure stoves, the high-pressure stove has been used for studying the thermal efficiency of vegetable oil fuels.

I.1 NEED OF PROJECT

If future program are to achieve their intended societal objectives and satisfy consumer requirements, research on designing improved stoves with lower emissions is critical. Integrated research will also be required on other related aspects, such as measurements of emissions from various stove bio-fuel combinations, and on developing improved procedures, evaluation and dissemination. The multiple benefits that can accrue from these programmers make continuing and increased investment of efforts worthwhile. Although on a global basis biomass accounts for about one-seventh of energy consumed, it is dose to being the only source of energy for over two billion of the world's poorest people. The increase in oil prices, however, made more remote the hope of a transition to these fuels for a substantial portion of the world's population and in fact in places there has been a return to traditional fuels. In densely populated areas, past unsustainable use of firewood has created a scarcity that forces people to turn to even poorer biomass materials: twigs, leaves, agricultural residues and animal dung. Because modem fuels can be burnt more completely and at higher efficiencies than traditional, solid biomass fuels, using modem fuels could possibly reduce the emissions of CO_2 in the short term, depending on the extent to which the source of biomass was being regenerated. In the longer term from a greenhouse perspective, clean, efficient and entirely sustainable use of bio-fuels (upgraded! would be preferable to increased use of fossil fuels.

II. Experimentation

II.1 Construction of stove

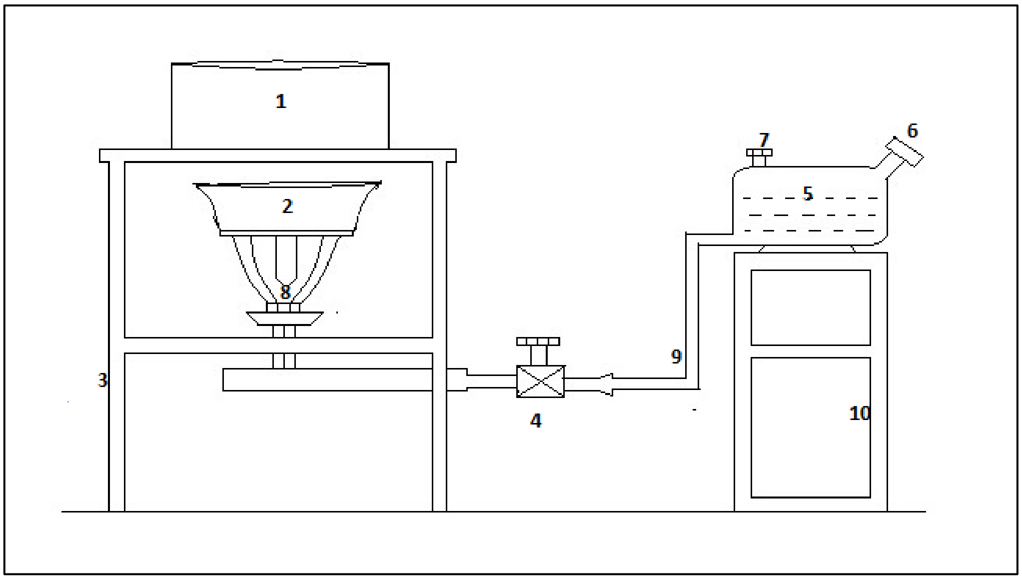


Fig. 1: Experimental set up of Stove.

1. Aluminium vessel
2. Burner
3. 10. Frame
4. Regulating Valve
5. Fuel storage tank
6. Pressure valve
7. Pressure release valve
8. Nozzle
9. Fuel supply line

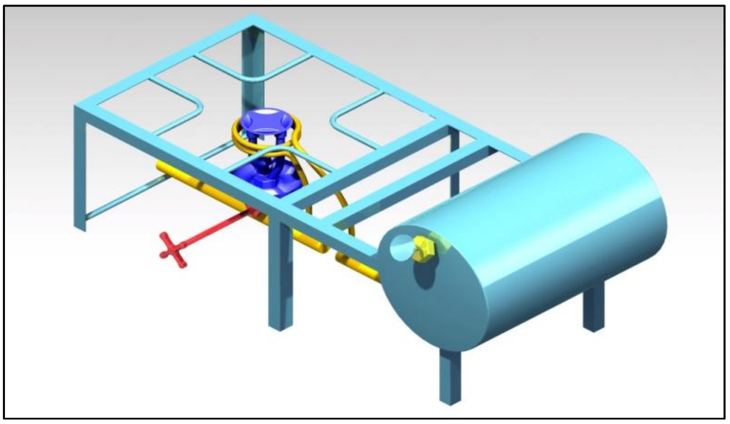


Fig.2: 3-D View of Modified Horizontal Kerosene Stove.

II.2 MODIFICATIONS IN THE STOVE

It is seen from the literature that the German universities have work on vegetable oil stove with independent tanks pressurized to around 2 bar pressure or by keeping the fuel tanks at higher level for supplying the fuel.

In our studies the standard stove available in market was use with minor addition/ modification in the pipe line. i.e. "fuel tank placed 10cm above from the base and a capillary phenomenon is introduced before the fuel entering in the nozzle". The capillary phenomenon is introduced for preheating the fuel before entering in nozzle.

As shown in Fig 3. Horizontal pressurized kerosene stove, consists of a fuel tank of capacity 2 liters at the side, along with a main fuel pipe attached to the burner assembly. The tank is pressurized by means of a small hand pump integrated into the tank.

Fig 4. Shows the working burner assembly. Kerosene with the aid of air pressure forced from the fuel tank passes to the burner through main fuel supply pipe and raises through the rising tube (A) through the ascending pipe (B) to the pre- heated burner head (C), where the fuel is heated and vaporized.

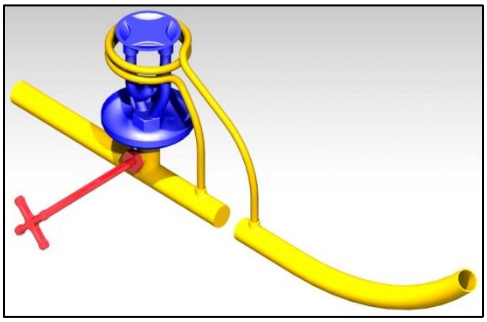


Fig.3: Pictorial View of Nozzle.

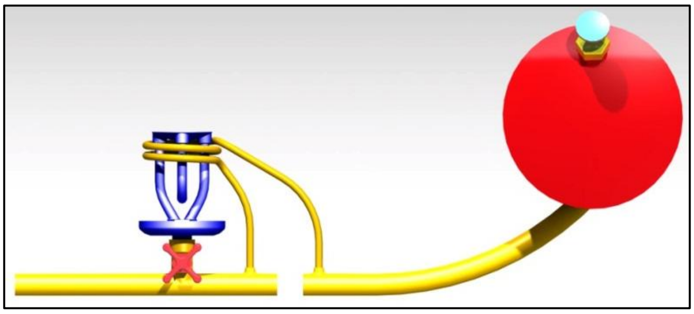


Fig.4: Pictorial View: Modified Fuel Supply Line

Fig.5: Horizontal Type Pressurized Kerosene Stove

The gas produced from the kerosene flows further on, and through a narrow opening, the jet mixes with the air outside where it bums with a blue, smokeless flame, turning a small "air screw" (usually located in the filler cap) will release pressure from the tank and make the flame smaller.

The purpose of this modification is to utilize the waste energy radiated from the burner thus reducing viscosity of oil blends. In addition, the flow control valve is placed between the burner and the coil so As to control the flow rate of the fuel. Other Equipment used in the Water Boiling Test Are: Pressure gauge manufactured by Japsin Instrumentation, of least count $0.05 kg/cm^2$, and Max. $2.1\ kg/cm^2$, Electronic weighing balance (Sansui) make, of least count 1 gm. and minimum of 10gm and maximum of 5kg. Apparatus Setup: An aluminium vessel is taken for heating water and a lid of same material is used to cover the utensil. The lid provided is drilled and thermometer of range 0°C - 100°C is fitted through a cork and made to pass through the lid into the utensil. A stirrer is also made to pass through the lid and to the water for its uniform heating.

II.3 Test for thermal efficiency

Fuel Consumption Test

The stove whose efficiency is to be determined shall be filled with kerosene up to three-fourth of its capacity. Allow the stove to burn for 10 minutes during which it should be adjusted to attain its maximum blue flame height. Place a 2mm thick flat steel plate, covering the flame of the lighted stove and the lighted stove shall be weighted on a sensitive dial balance with an accuracy of 1g. the stove shall be allowed to burn for one hour with an aluminium vessel having sufficient water in it. The stove shall be weighted again after removing the vessel and with the flame covered by the same flat steel plate of 2mm thick. The difference in initial and final weight of the burning stove shall give the fuel consumption rate in g/h.

A suitable vessel size and quantity of water to be taken for determining the thermal efficiency shall be selected from table given below depending upon the fuel consumption rate.

Table 1: Aluminium Vessels for Thermal Efficiency Test.

Fuel Consumption rate g/hr	vessel diameter (External) ±5mm	Vessel Height (External) ±5mm	Total Vessel Weight With Lid g (±10%)	Weight of Water in Vessel Kg
1	2	3	4	5
Up to 100	180	100	356	2
101 to 130	205	110	451	2.8
131 to 150	220	120	519	3.7
151 to 180	245	130	632	4.8
181 to 200	260	140	750	6.1
201 to 240	285	155	853	7.7
241 to 270	295	165	920	9.4
271 to 300	320	175	1100	11.4

The test is conducted by heating water in flat bottomed aluminium vessels (size of the vessel and quantity of water to be taken are selected from table depending upon fuel consumption rate) and provided with aluminium lid having two suitable holes, one for inserting a cork for holding thermometer and other for stirrer of aluminium wire required for stirring the water. The vessel bottom from inside shall have bright finish. The water in the vessel is heated from initial temperature of 25±2◦c to temperature below the boiling point of water. Thermal efficiency is then calculated by dividing the heat absorbed by the vessel and water to heat supplied by the kerosene consumption.

Trim the wicks uniformly as per direction of the manufacturer, if provided. Again check the kerosene level in the fuel tank which should be approximately three-fourth of the tank capacity. Take two aluminium vessels and fill them with water (size of the vessel and quantity of water to be taken are selected from table depending upon the fuel consumption rate) at a temperature of 25±2◦C which has been achieved by adding ice or cold water/ hot water or tap water. Fit the stirrer and thermometer on the vessel lid. Light the stove and adjust the wicks till it gives blue flame at maximum flame height. Operate the stove for 10min. under maximum blue flame conditions. Note the weight of the lighted stove with the flame covered by two mm thick flat steel plate and start a stop watch at the time of recording initial weight of the burning stove. Put the vessel on the stove and start immediately second stop watch. Heat the water while stirring with the help of stirrer till it attains the temperature of 5◦c below the boiling point. Note the time required to heat the water from initial temperature (25±2◦c) to the final temperature, i.e. (5◦c below B.P), in the second case. Leave the vessel on the stove and let it burn for 1 hr. At the end of 1 hr., remove the vessel and note the weight of the lighted stove with the flame covered with the same flat steel plate of 2mm thick. The difference in the initial and final weight of burning stove shall give the kerosene consumption rate in g/h. Thermal efficiency shall be calculated for two different vessels. If the individual thermal efficiency values differ by more than 4% the complete test shall be repeated.

In case an hourly fuel consumption obtain during test as per above point , above the highest or below the lowest limit of the range of kerosene consumption rate on the basis of which the vessel was selected earlier, then the test should be repeated with a vessel based upon fuel consumption obtained during test as in above point. The average thermal efficiency calculated as in above point and this point would give thermal efficiency of the stove.

$$Thermal\ Efficiency = \frac{((W\times 0.896)+(w\times 4.187)(\Delta T))}{(X\times T\times CV)}$$

Where,
W= Mass of Vessel Complete With Lid and Stirrer in Kg
w = Mass of Water in Vessel In Kg
t_1= Initial Temperature of Water in ◦C
t_2= Final Temperature of Water in ◦C
X= Mass of Fuel Consumed Per Hour in Kg
T= Time Taken To Heat Water From t_1 To t_2 in Min.
$C_{p_{Al}}$= Specific Heat of Aluminium Vessel (0.896$^{Kj}/_{Kg℃}$)
C_{p_w} = Specific Heat of Water (4.187$^{Kj}/_{Kg℃}$)

III. Observation Tables

For Kerosene 100%:-

Table 2: observation table for kerosene 100%

W	Cp_{Al}	$W \times Cp_{Al}$	W	Cp_w	$w \times Cp_w$	t_1	t_2	ΔT
0.356	0.896	0.318976	2	4.187	8.374	29.5	80	50.5
0.356	0.896	0.318976	2	4.187	8.374	29	80	51
0.356	0.896	0.318976	2	4.187	8.374	30	80	50
0.356	0.896	0.318976	2	4.187	8.374	28	80	52
0.356	0.896	0.318976	2	4.187	8.374	28.5	80	51.5

N^r	X	T	$CV_{kerosene}$	D^r	η_{th}	η_{avg}
438.9953	0.000255	317.4	43960	3559.386	12.33346	
443.3418	0.00025	312	43960	3428.88	12.92964	
434.6488	0.000236	309	43960	3208.456	13.54698	13.52958
452.0348	0.000234	307.2	43960	3164.107	14.28633	
447.6883	0.000198	354	43960	3076.576	14.55151	

For Blend 80:20:-

Table 3: Observation table for blend 80:20

W	Cp_{Al}	$W \times Cp_{Al}$	w	Cp_w	$w \times Cp_w$	t_1	t_2	ΔT
0.356	0.896	0.318976	2	4.187	8.374	29	80	51
0.356	0.896	0.318976	2	4.187	8.374	29.5	80	50.5
0.356	0.896	0.318976	2	4.187	8.374	28	80	52
0.356	0.896	0.318976	2	4.187	8.374	28.5	80	51.5
0.356	0.896	0.318976	2	4.187	8.374	27.5	80	52.5

N^r	X	T	CV_{blend}	D^r	η_{th}	η_{avg}
443.3418	0.000238	378.6	43097.6	3878.492	11.43078	
438.9953	0.000139	448.8	43097.6	2688.566	16.32823	
452.0348	0.000195	328.2	43097.6	2763.861	16.35519	15.51096
447.6883	0.000188	336	43097.6	2715.149	16.48854	
456.3812	0.000193	324	43097.6	2692.186	16.95207	

For Blend 60:40:-

Table 4: Observation table for bled 60:40

W	Cp_{Al}	$W \times Cp_{Al}$	w	Cp_w	$w \times Cp_w$	t_1	t_2	ΔT
0.356	0.896	0.318976	2	4.187	8.374	28	80	52
0.356	0.896	0.318976	2	4.187	8.374	29	80	51
0.356	0.896	0.318976	2	4.187	8.374	28.5	80	51.5
0.356	0.896	0.318976	2	4.187	8.374	29.5	80	50.5
0.356	0.896	0.318976	2	4.187	8.374	30	80	50

N^r	X	T	CV_{blend}	D^r	η_{th}	η_{avg}
452.0348	0.000222	324	42235.2	3037.893	14.87988	
443.3418	0.000265	328.2	42235.2	3673.322	12.06923	
447.6883	0.000214	331.2	42235.2	2997.692	14.93443	13.39745
438.9953	0.000242	330	42235.2	3378.478	12.99388	
434.6488	0.000255	333	42235.2	3589.215	12.10986	

For Blend 70:30:-

Table 5: Observation table for blend 70:30

W	Cp_{Al}	$W \times Cp_{Al}$	w	Cp_w	$w \times Cp_w$	t_1	t_2	ΔT
0.356	0.896	0.318976	2	4.187	8.374	26.5	80	53.5
0.356	0.896	0.318976	2	4.187	8.374	27	80	53
0.356	0.896	0.318976	2	4.187	8.374	29	80	51
0.356	0.896	0.318976	2	4.187	8.374	28	80	52
0.356	0.896	0.318976	2	4.187	8.374	27.5	80	52.5

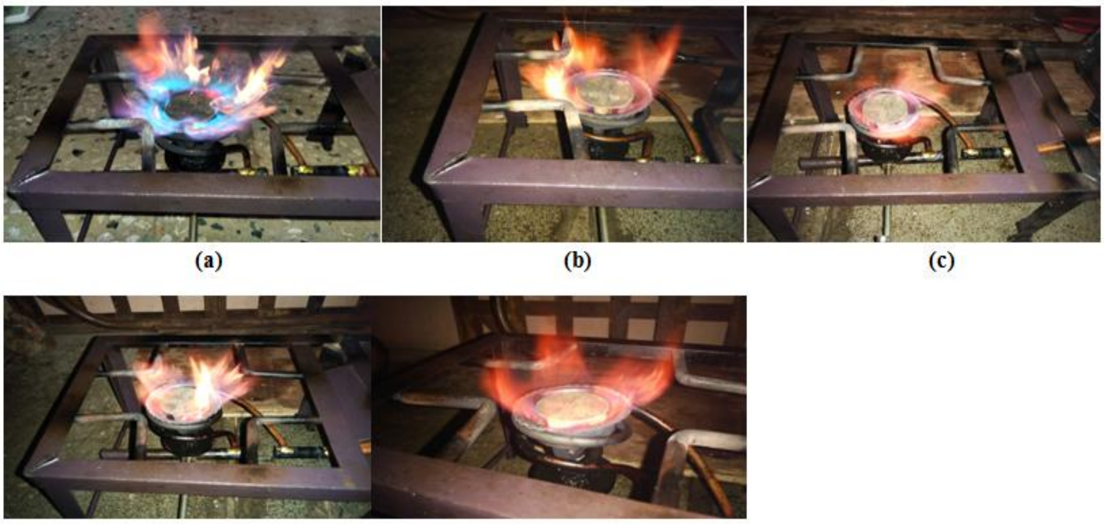
N^r	X	T	CV_{blend}	D^r	η_{th}	η_{avg}
465.0742	0.000192	402	42666.4	3284.587	14.15929	
460.7277	0.000179	414	42666.4	3156.537	14.59599	
443.3418	0.000203	360	42666.4	3113.453	14.23955	14.24029
452.0348	0.000202	372	42666.4	3199.775	14.12708	
456.3812	0.000195	390	42666.4	3241.452	14.07953	

For Blend 50:50:-

Table 6: Observation table for blend 50:50

W	Cp_{Al}	$W \times Cp_{Al}$	W	Cp_w	$w \times Cp_w$	t_1	t_2	ΔT
0.356	0.896	0.318976	2	4.187	8.374	29	80	51
0.356	0.896	0.318976	2	4.187	8.374	28	80	52
0.356	0.896	0.318976	2	4.187	8.374	28.5	80	51.5
0.356	0.896	0.318976	2	4.187	8.374	27.5	80	52.5
0.356	0.896	0.318976	2	4.187	8.374	27	80	53

N^r	X	T	CV_{blend}	D^r	η_{th}	η_{avg}
443.3418	0.000218	325.8	41804	2967.742	14.93869	15.62325
452.0348	0.000199	321	41804	2674.423	16.90214	
447.6883	0.000218	330.6	41804	3008.702	14.87978	
456.3812	0.000215	312	41804	2800.299	16.29759	
460.7277	0.000225	324	41804	3051.575	15.09803	



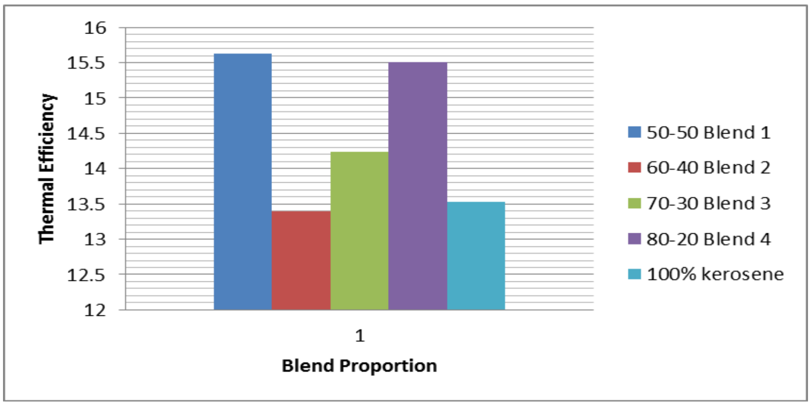
(a) (b) (c)

(d) (e)

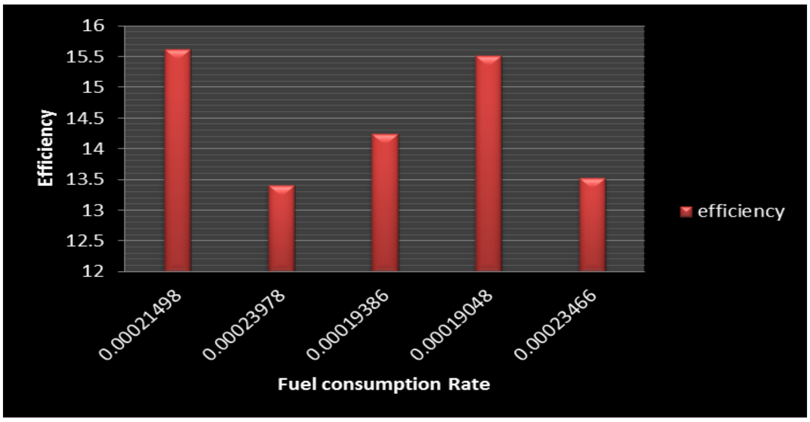
Fig.6: (a) Flame of 100% kerosene,(b) Flame of 80:20 blend, (c) Flame of 70:30 blend, (d) Flame of 60:40 blend, (e) Flame of 50:50 blend.

IV. Result & Discussion

To understand performance of modified horizontal pressure stove, we have performed various test with kerosene and cottonseed oil blended with kerosene. Also a test of water boiling was performed.
We have taken various blends like;
80:20 (80% kerosene and 20% cottonseed oil)
70:30 (70% kerosene and 30% cottonseed oil)
60:40 (60% kerosene and 40% cottonseed oil)
50:50 (50% kerosene and 50% cottonseed oil)



Graph 1: Blend Proportion Vs Thermal Efficiency



Graph 2: fuel consumption rate vs. efficiency

First of all the test using 100% kerosene were performed. Experimentally the thermal efficiency using 100% kerosene was 13.59%. Also same test on cottonseed oil blends with kerosene were performed (80:20, 70:30, 60:40, 50:50). The thermal efficiency for 80:20 blend got up to 15.59% which is 1.92% greater than thermal efficiency of 100% kerosene. The thermal efficiency for 70:30 blend got up to 14.24% which is 0.65% greater than thermal efficiency of 100% kerosene. The thermal efficiency for 60:40 blend got up to 13.39% which is 0.2% greater than the thermal efficiency of 100% kerosene. The thermal efficiency for 50:50 blend got up to 15.62% which is 2.03% greater than the thermal efficiency of 100% kerosene.
It clearly shows that, cottonseed oil blend with kerosene having thermal efficiency more than thermal efficiency of 100% kerosene.

This clearly shows that the modification in stove such as copper tube in fuel supply line to maintain the viscosity of blends by using capillary action has resulted in improvement in thermal efficiency using cottonseed oil blends with kerosene oil. Also a modification like increasing the height of fuel tank from ground has resulted in proper supply of fuel because of gravity fuel comes into nozzle at lower pressure also, which may reduce the effort of operator.

In the present experiment, horizontal type kerosene stove was modified to burn higher percentage of cottonseed oil blends with kerosene. In normal kerosene stove the copper coil is incorporated to absorb the heat radiated through burner and heat up the blend to reduce its viscosity. The heat which is utilised to heat up the blend is the waste heat. The results are highly encouraging the normal stove could burn with a maximum of 40% blend with kerosene (40% cottonseed oil and 60% kerosene)

However, in the modified kerosene stove 50% blend could be easily burnt and with thermal efficiency of almost same as kerosene operated stove. A comparison of thermal efficiency of various tests blends for modified horizontal type kerosene stove is plotted on the graph. It can be observed that for all blends the modified stove were performing better when operated on blends of cottonseed oil than kerosene.

V. Conclusions

1. The modified horizontal pressure stove is fuelled by kerosene and various blends of cottonseed oil and water boiling test is carried out referenced from Bureau of Indian standards for kerosene pressure stove.
2. The maximum blend that could be burned in modified stove is CSO40 with thermal efficiency 13.39%.
3. The maximum thermal efficiency of modified stove was observed at blend CSO50 with thermal efficiency 15.62%.
4. In modified pressure stove it is observed that the efficiency of blends of cottonseed oil is more than the thermal efficiency of kerosene.

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