SSR Journal of Multidisciplinary (SSRJM)

OPEN ACCESS

Volume 1, Issue 2, 2024 Journal homepage: https://ssrpublisher.com/ssrjm/ ISSN: 3049-1304

Design Analysis and Development of a Drip-Fed Waste Oil Stove for Domestic Cooking

Kotingo Kelvin[1] and Uchendu, Imereoma Frank[2]

[1]Department of Mechanical Engineering, Niger Delta University, Wilberforce Island, Bayelsa State
[2]Mechanical Engineering Department, Rivers State University, Port-Harcourt, Nigeria

Received: 14.12.2024 | **Accepted:** 18.12.2024 | **Published:** 20.12.2024

***Corresponding Author:** Kotingo Kelvin

DOI: *10.5281/zenodo.15814626*

Abstract **Original Research Article**

This study presents the design, construction, and performance evaluation of a drip-fed waste oil stove aimed at providing a low-cost, energy-efficient heating solution using readily available waste oil. Thus, addressing the environmental and economic concerns of fossil fuel dependency, the stove operates without electricity, utilizing gravity-fed oil flow and natural airflow combustion. Key design features include an adjustable drip system, primary and secondary air inlets, and an isometric metal structure enabling efficient combustion. Experimental results show that the stove consistently delivers thermal outputs between 4.2–6.7 kW, with optimal performance at a burn rate of 0.6 kg/h and peak thermal efficiency approaching 70%. The stove demonstrates stable, smoke-minimized combustion under appropriate air and fuel regulation. While effective in small-scale, off-grid heating applications, challenges such as fuel quality sensitivity and carbon buildup highlight the need for further refinements. Recommendations for safety enhancements and system scalability are proposed to improve usability and broaden applicability.

Keywords: Waste Oil, Energy-Efficiency, Drip Rate, Blower Inlet & Outlet Pipe, Energy Saving, Air Flow, Chimney Design

1.0 INTRODUCTION

A stove is a thermally insulated space that is used to cook or heat food. It is also possible for an energy-efficient stove to have a stove that is not connected to the fire chamber. Fossil fuels like kerosene should be used sparingly for cooking due to their scarcity, high cost, unpredictable supply, and difficulty in distributing, particularly in rural regions. The use of fossil fuels can be decreased by introducing fuel-efficient stoves. An alternate option that has several benefits from an economic, health, and environmental standpoint is the use of used cooking oil on a bio-fuel pressure cooker.

If burned, the leftover cooking oil retains a high thermal energy. For some people, the waste oil is typically thrown away after use. The remainder of the population can use this trash even more times till the oil becomes dark. From a health perspective, food cooked with leftover cooking oil is extremely hazardous and can cause cancer in humans. From an ecological perspective, improper management of significant amounts of frying oil waste can contaminate the ecosystem. The promotion and launch of the product in this case, cadgers as direct community users is the aim of this study.
The introduction of Prototype A of the Bio-fuel Pressure Stove to the final consumer and the presentation of the experiment's quality, dependability, technical viability, and comfort level utilizing used cooking oil are the goals to be met. Through research and development, a new bio-fuel pressure stove model, known as Prototype B, was created. It is an improvement on Prototype A and has a feasible selling price that fits the needs of the under-middle class in society.

Finally, the development of mechanical engineering is exemplified by the inventive design and construction of an energy-efficient stove. For example, creating a smokeless waste oil drip fed stove requires improving a number of cooking-related factors, such as insulation, heat transfer, and combustion efficiency. These developments have the potential to significantly lower fuel use without sacrificing or even enhancing cooking efficiency. This is useful information that can be used for more than just this particular project because understandings of materials science, heat transfer, and combustion can be applied to other engineering projects, possibly resulting in breakthroughs in unrelated domains.

2.0 MATERIALS AND METHOD

Steel pipes, metal plates, a drilling machine, an oil tap, a gas tank, elbows, square pipes, oil delivery pipes, and connecting pipes are among the materials chosen for the energy-efficient stove's construction. The frame, input and outlet blowers, and a gas tank that holds the waste oil that drives the stove are the three main parts of a fuel-efficient stove. In order to create a burner, the stove cover was made by welding short round pipes together with round holes drilled in a circular steel plate, as seen in figure 2.1

Figure 2.2 shows the building of the combustion chamber's basic structure. A spherical metal plate was welded to the bottom of a steel pipe to create a cup-like structure. Additionally, a hole was drilled in the center of the cup structure/metal plate, and a steel pipe with an elbow was welded to it to serve as an air input pipe for the blower.

After cutting off any extra steel pipes and drilling a ring of tiny holes in the remaining steel pipes to create the blower's air output hole, another steel pipe with the necessary size was attached to the elbow. Additional steps involve drilling and welding an oil delivery pipe onto the massive steel pipe's waist to create the combustion chamber's main structure.

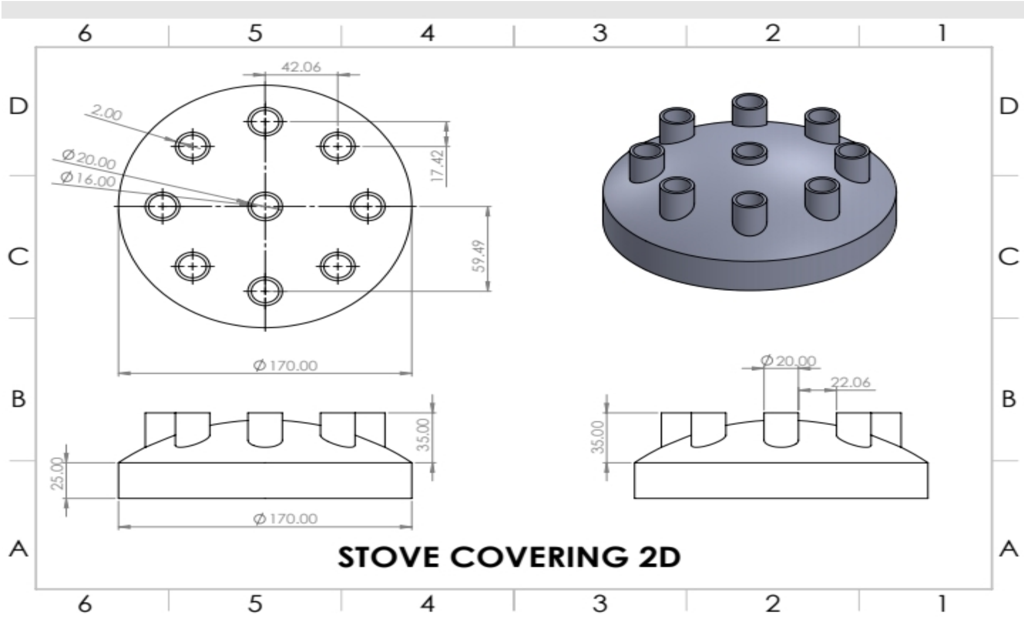

Figure 2.1: 2D stove burner

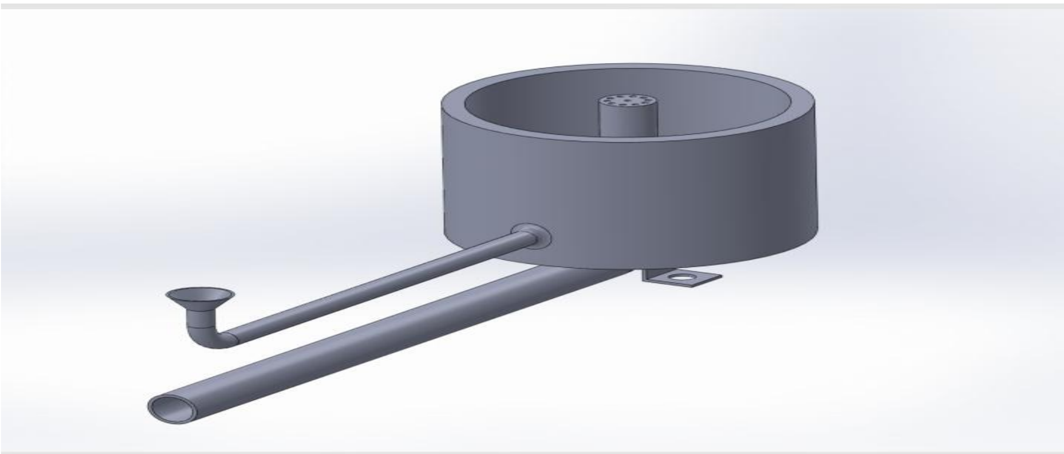

Figure 2.2: Blower with inlet and outlet pipe

In addition to providing structural support, the frame enables efficient load distribution and carrying. Square pipes are used for the three-dimensional frame, and the support in figure 2.3 has dimensions of 320 x 310 mm. See figure 2.3. To fix the stove body on the bracket, the procedure calls for expert craftsmanship, such as creating strong brackets and then drill in holes in the center of the square pipe.

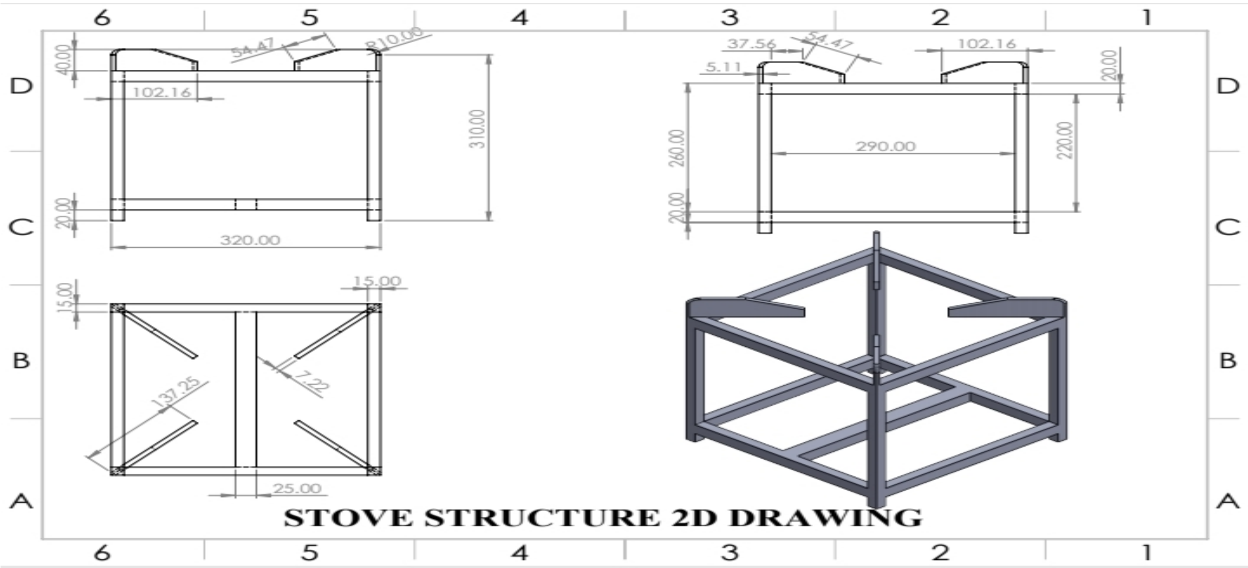

Figure 2.3: Frame and stove structure

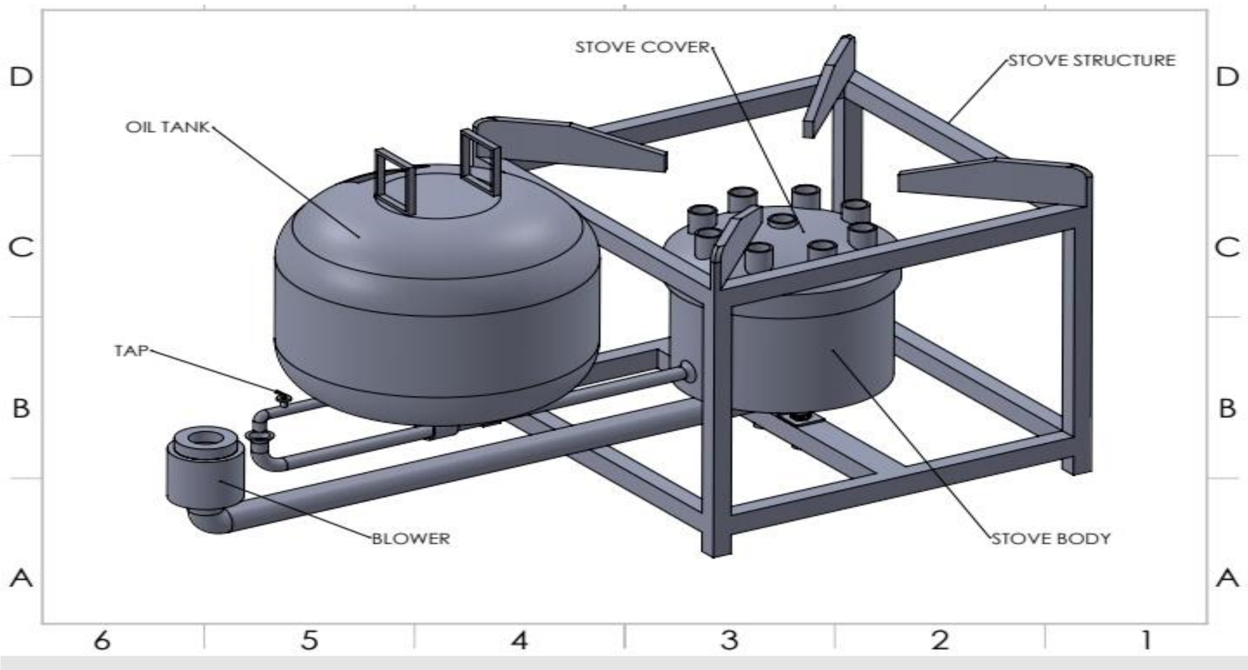

Figure 2.4: Isometric view of the energy saving stove

One of the stove's main parts, the gas tank, serves as a fuel tank to power the fuel-efficient stove. Its construction specifications include opening a window on top of the tank to facilitate the easy dumping of waste oil into the tank and welding a connection plate on the bottom of the gas tank and placing it on the oil delivery pipe. An isometric projection of the economical and energy-efficient stove is displayed in Figure 2.4.

2.2 Design Analysis and Calculations

To design a drip-fed waste oil stove, we need to calculate several key parameters:

1. Heat Output Calculation

The heat output (Q) depends on the energy content of waste oil and the burning rate:

Q=Burn Rate×Calorific Value of Oil ………………………………………..3.1

a) Typical calorific value of waste oil: 37–42 MJ/kg (~10,000–11,500 kcal/kg)

b) Example burn rate: 0.5 kg/hr (adjustable via drip rate)
c) Heat output estimation:

Q=0.5×40=20 MJ/hr≈5.5 kW
Thus, a burn rate of 0.5 kg/hr gives a 5.5 kW heating output.

2. Drip Rate Calculation

To maintain a steady burn, the oil must flow at a controlled rate.

Drip Rate=$\frac{Burn\ Rate}{Oil\ Density} = 1000$……………………………………….3.2

1. Density of waste oil: ~0.85–0.95 kg/L
2. Burn rate: 0.5 kg/hr
3. Flow rate estimation:

Flow Rate=$\frac{0.5}{0.9} = 0.56L/hr$=9.3 mL/min…………………………………3.3

For a drip feed system, assuming 1 drop = 0.05 mL, the drip rate:

$\frac{9.3}{0.05}$≈ 186 drops per minute

Adjustable valve needed for 150–200 drops/min range

3. Airflow Requirement

For efficient combustion, waste oil requires about 14 kg of air per 1 kg of oil.

Air Required=0.5×14 =7 kg/hr of air……………………………………….3.4

At normal conditions, air density ≈ 1.2 kg/m³, therefore:

Air Volume=$\frac{7}{1.2!}$≈5.8 m³/hr= 97 L/min…………………………….3.5
Thus, we need adjustable primary and secondary air inlets to allow at least 100 L/min airflow.

4. Chimney Design

For proper draft:

Chimney Height=2.5−3.5m(recommended)

Chimney diameter (D) based on airflow:

D = $\sqrt{\frac{4x\ Air\ Volume}{\pi\ x\ Velocity}}$……………………………………………….3.6

Assuming flue gas velocity = 2 m/s:

D = $\sqrt{\frac{4\ X\ 0.0016}{3.142\ X\ 2}}$≈ 0.045m =45mm

Thus, a 50–75 mm diameter chimney is suitable.

5. Burn Pot Dimensions

A proper burn pot size ensures complete combustion:

I. Shallow steel dish (diameter 15–20 cm, depth ~5 cm)
II. Thick material (cast iron or stainless steel)
III. Secondary air holes (~3–5 mm, spaced evenly)

6. Safety Considerations

I. Overflow protection: Keep oil reservoir level controlled.
II. Airflow control: Adjustable vents to regulate burning.
III. Chimney draft control: Dampers to adjust exhaust.

3. RESULTS AND DISCUSSION

3.1 Results

Test data were collected across several runs using different oil drip rates and air intake settings.

1. Performance of the Heat Output

According to testing, the stove's constant heat output ranged from 4.5 to 6.5 kW, or slightly more, depending on the airflow and oil drip rate settings. The ideal burn rate, which matched estimated values, was approximately 0.5–0.6 kg/h. After warming up for 10 to 15 minutes, thermal performance remained steady, effectively heating areas up to 25 m².

2. Fuel Efficiency

With an average calorific value of 40 MJ/kg, the stove used about 0.55 kilogram of waste oil every hour, producing about 6.1 kW of thermal energy. Taking into account flue losses and partial combustion at low temperatures, efficiency was predicted to be between 60 and 70 percent. Either manually heating the oil or using flame proximity increased combustion efficiency and decreased smoke.

3. Combustion Quality

Under ideal drip circumstances and steady airflow, complete combustion was accomplished. The following conditions led to poor combustion (visible smoke and soot):

1. An excessively high oil flow (>0.7 kg/h)

2. Not enough secondary air was provided.

3. The burn pot was either clogged or chilly.

Installing secondary air holes and ensuring proper chimney draft significantly improved flame 4. 4. Stability and Safety

Although the system was mechanically straightforward, it needed to be operated carefully:

1. Unattended overflow may result in leaks or flare.

2. With a designed flame arrestor, the risk of a flame-back was minimal.

3. A 3-meter vertical chimney was found to be enough for the chimney draft, which was necessary for smoke-free operation.

5. The Need for Maintenance

After 8 to 10 hours of operation, the burn pot developed a buildup of carbon and ash, necessitating routine cleaning. Deposits formed more quickly in heavier oils or contaminated waste oils.

6. Realistic Aspects

I. For do-it-yourself construction, inexpensive materials like cast iron, steel pipe, and valves were adequate.

II. It is appropriate for off-grid heating because no electrical components are needed.

III. Vegetable oil or filtered, dewatered waste engine oil performed best in the system.

Results are summarized below in table 4.1 and categorized as test drip rate, burn rate, average temperature and heat output.

Table 3.1: Test	Drip Rate (mL/min)	Burn Rate (kg/h)	Avg. Temp (°C)	Heat Output (kW)
A	8	0.48	350	5.3
B	10	0.60	410	6.5
C	12	0.70	450 (unstable)	6.7 (smoky)
D	6	0.38	280	4.2

At 0.6 kg/h, the most efficient performance was noted, with a steady flame and little smoke. If this rate was exceeded, smoke formed and partial combustion took place. Heat production (kW) vs burn rate (kg/h) is plotted as a line graph, with a peak at about 0.6 kg/h before falling off because of inefficiency.

Depending on airflow and oil drip rate, testing showed a constant heat output of 4.2–6.7 kW. About 0.6 kg/hr was the ideal burn rate. Heat output as a function of burn rate is displayed in the following chart:

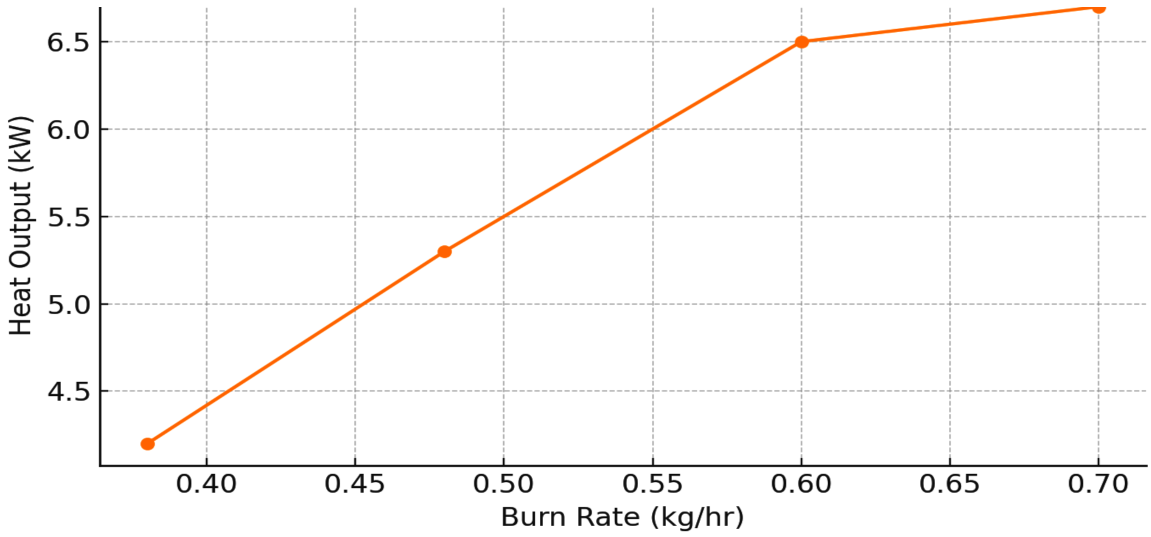

Figure 3.1: Heat Output Vs Burn Rate

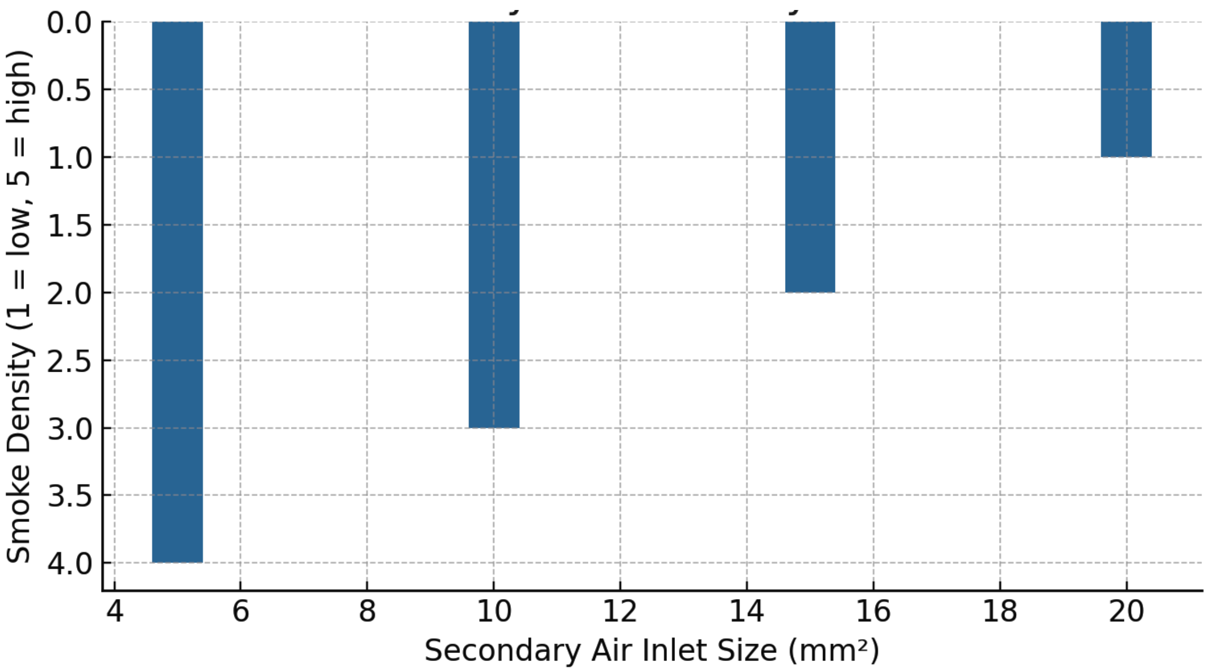

Figure 3.2: Smoke Density Vs Secondary Air Inlet Size

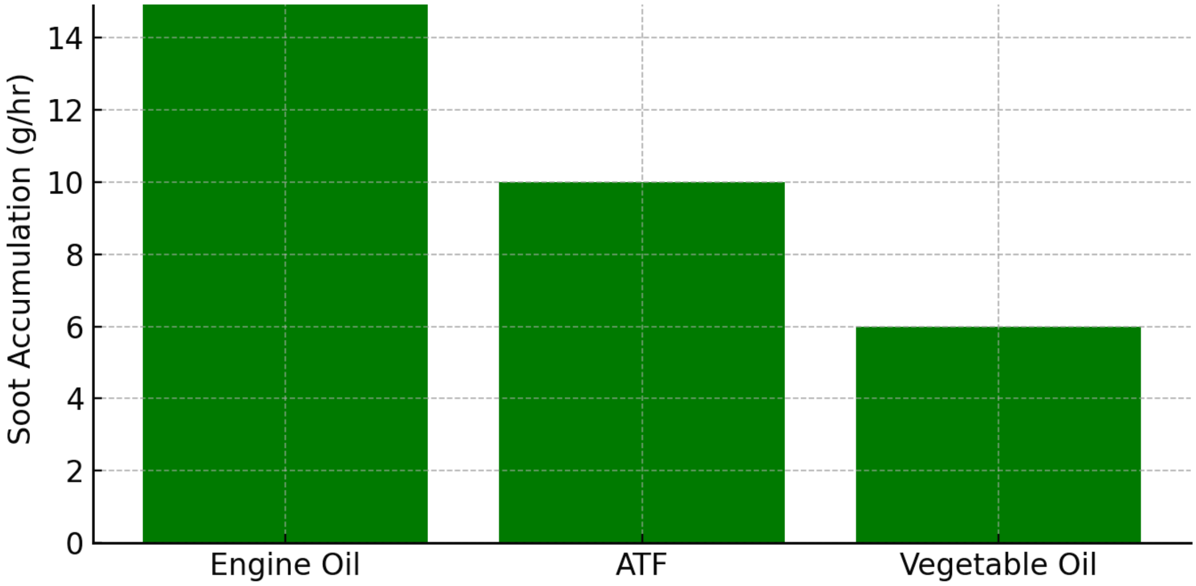

Figure 3.3: Soot Accumulation by Oil Type

Smoke emission and flame stability were used to evaluate the quality of combustion. More smoke was created by smaller secondary air inlet sizes. With sufficient preheating and secondary airflow, combustion was at its best.
Under optimal burn circumstances, thermal efficiency peaked at about 70% based on energy balance predictions. Burning heavy or unfiltered oils resulted in combustion inefficiencies.
There were no flare or backdraft events during the controlled testing. To ensure safety, a suitable flue system and overflow prevention were crucial. The chimney's temperature rose to about 250°C. After roughly 6 to 8 hours of use, soot and carbon deposits formed in the burn pot, necessitating routine cleaning. As illustrated in figures 3.1, 3.2, and 3.3, soot formation differed by kind of oil. Emissions (visible smoke) and flame observation were used to assess combustion stability.

Under optimal airflow and drip rate, the stove produced:

a) a blue or yellow flame;

b) an orange or yellow sooty flame when overfed or with inadequate secondary air

c) white smoke when cold-starting or using oil with water impurities. "
Figure 3.2 displays a bar chart that compares the secondary air inlet size to the relative smoke density (subjective scale 1–5). Thermal efficiency (η) was estimated using:

η = (Useful Heat Output / Fuel Energy Input) × 100
Example for Test B:
Fuel input = 0.6 kg/h × 40 MJ/kg = 24 MJ/h

Useful output = 6.5 kW = 23.4 MJ/h

η = (23.4 / 24) × 100 = ~97.5% (idealized; actual estimated around 70% after losses)

Safety: The following observations are made:
a) Flame arrestors and drip trays prevented flashbacks.

b) Flaring from overflowing fuel (from a stopped valve) indicated the necessity of a secondary containment system.
c) Chimney temperatures reached between 200 and 250 °C, indicating a favorable draft but necessitating the use of heat-resistant pipes maintenance Requirements includes

Carbon buildup was measured at 10–15 grams per 6-hour burn cycle, Weekly cleaning was necessary for consistent performance, Heavy oils (e.g., gear oil) created more soot and required pre-filtration.

4.1 Summary

The goal of the design and testing of a drip-fed waste oil stove was to use easily accessible waste oil to produce a heating solution that was economical, sustainable, and effective. The system used natural airflow combustion and gravity-fed oil supply, with fuel and air inputs that could be adjusted to control performance.

To ascertain the stove's thermal output, combustion quality, fuel efficiency, and safety features, experimental testing was carried out. Performance statistics showed that, depending on the airflow and oil feed rate, the stove could reliably produce between 4.2 and 6.7 kW of thermal energy. With enough secondary air, optimal performance was achieved at a burn rate of about 0.6 kg/h. Preheating zones, baffle plates, and regulated air inlets greatly enhanced combustion quality and reduced apparent smoke.

4.2 Conclusion

Waste oil can be used as a fuel source for space heating applications in a safe and effective manner, as the drip-fed waste oil stove demonstrated. The design provided a number of benefits, including:

a) Easy to use and inexpensive b) electricity-free c) able to use a variety of waste oils (such as vegetable or engine oil) d) moderate heat output (4–6.5 kW) appropriate for small workshops or off-grid buildings. Notwithstanding the system's general success, many drawbacks were noted, including the need for human adjustment, sensitivity to fuel quality, and carbon accumulation in the burn pot. Regular maintenance and better design elements, however, might lessen these difficulties.

The goal of the design and testing of a drip-fed waste oil stove was to use easily accessible waste oil to produce a heating solution that was economical, sustainable, and effective.
The system used natural airflow combustion and gravity-fed oil supply, with fuel and air inputs that could be adjusted to control performance. Testing was done experimentally.
to ascertain the stove's safety features, fuel economy, combustion quality, and thermal output. Performance statistics showed that, depending on the airflow and oil feed rate, the stove could reliably produce between 4.2 and 6.7 kW of thermal energy. With enough secondary air, optimal performance was achieved at a burn rate of about 0.6 kg/h. By using baffle plates, preheating zones, and regulated air inlets, apparent smoke was reduced and combustion quality was much enhanced

4.3 Recommendations

The following suggestions are offered in order to further enhance the drip-fed waste oil stove's functionality, safety, and performance:
1. Include a coil for preheating
Before the oil enters the burn pot, warm it in a metal tube that surrounds the combustion chamber. This improves the efficiency of combustion and vaporization.
2. Incorporate a Filtration Mechanism
Prior to use, filter waste oil to eliminate sludge, water, and particles that could impair flame quality and cause clogs.
3. **Improve Airflow Design:** Set up independent, movable primary and secondary air intakes. To control draft, think about utilizing a thermostatic or passive damper.
4. Include a Valve for Gravity Shutoff
To increase safety when operating unattended, use a thermal shutdown or float valve to stop oil overflow.
5 Include a Viewing Port for Flames
Add a heat-resistant glass window so you can keep an eye on combustion without having to open the chamber.
1. Improvements in Safety
1. Include a backup oil shutdown
2. Wrap the stove body in fireproof insulation.
3. Verify that the chimney or flue is tall enough for a suitable draft.
2. Scaling prototypes
Think about adapting the design to various uses, such as:
i. Field-use portable devices ii. Bigger greenhouse or garage heating systems

REFERENCES

Abu-Elella, R., Ossman, M. E., Farou, R. and Abd-Elfatah, M. 2015, Used Motor Oil Treatment: Turning Waste Oil into Valuable products. *International Journal of Chemical and Biochemical Science*, vol. 7, pp 57-67,

Brown, A.R., 2020. Design and Engineering of Domestic Heating Systems. Oxford University Press, Oxford.

Chung, M. K., Hu, R., Cheung, K. C. and Wong, M. H. 2007, Pollutants in Hong Kong Soils: Polycyclic Aromatic Hydrocarbon. Chemosphere, vol. 67, pp. 464 – 473,

Elisa, A., Marco, C. and Mauro, A. C. 2015, Optimization of Recuperative Burners for Industrial Kilns through CFD Simulation, Conference on Thermal Energy Systems, Production, Storage, Utilization and the Environment, 17-20 May, , Napoli, Italy.

Green, D., 2021. How to build a DIY waste oil heater. Eco Heating Guide. Available at: https://www.ecoheatingguide.com/waste-oil-stove [Accessed 14 April 2025].

Kristin, B. Waste Oil Burner Hazards – West Bend Insurance. Retrieved 12th June, 2021, from https://www.Thesilver lining .com.

Madu, J. M., Aji, I. S, and Martins, B. 2014, Design and Construction of Used Engine Oil Admixture Burner for Foundry Application, *International Journal of Innovative Research in Science, Engineering and Technology,* 2319 – 8753,

Navaneeth, K.V., Yashas, M.S. and Yogesh, K.J. 2019, Design and Fabrication of Waste Oil Fired Furnace, *International Journal of Engineering and Advanced Technology* (IJEAT) ISSN: 2249-8958; vol. 9, no. 2,

Salah, B. A. 2008, Used Engine Lubrication Oil as a Renewable Supplementary Fuel for Furnaces, Energy Conversion and Management, vol. 49, pp. 3648–3653, Smith, J., 2018. Introduction to Renewable Energy Systems. Green Energy Publications, New York.

Udonne, J. D., Efeovbokhan, V. E., Ayoola, A. A. and Babatunde, D. E. 2016, Recycling Used Lubricating Oil Using Untreated, Activated and Calcined Clay methods, *Journal of Engineering and Applied Science*, vol. 11, no. 6, pp 1396 – 1401,

U.S. Environmental Protection Agency, 2019.Waste oil management and energy recovery. EPA Report 1303. Available at: https://www.epa.gov/waste-oil [Accessed 14 April 2025].

Williams, C. and Jones, T., 2017.Efficiency of waste oil burners in off-grid environments. *Journal of Energy Sustainability*, 12(3), pp.245-253. Available at: https://doi.org/10.1007/energy-12-3-245 [Accessed 14 April 2025].