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# Utilization of used oil waste for boiler energy source

**Akbar Pribadi, Theresia Prima Ari Setiyani, Tjendro, Budi Setyahandana and Martanto***

Dept of Electrical Engineering, Sanata Dharma University, Yogyakarta, Indonesia

* Corresponding author: martanto@usd.ac.id

**Abstract**

Oil is one type of lubricating oil whose usage is increasing every year. The increase in oil usage automatically leads to an increase in waste generated. Used oil waste falls into the category of hazardous and toxic waste that requires special handling and processing. Used oil waste can be utilized as a valuable energy source with high economic

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will consist of three main plant components: the Burner, plasma burner, and boiler. The used oil waste will be used as the primary fuel without any mixture for combustion. The waste oil will be heated in a spiral pipe to reach its boiling point, generating combustible gas steam. This flame energy source will be processed in the plasma burner to increase the flame pressure for boiler combustion. Control of the burner tank will be automated, making it easier for operators to manage the availability of burner fuel. Sensors will read the levels in burner tanks 1 and 2 to control the on-off operation of the oil pump. The values obtained by the sensor will be displayed on an LCD screen and can be monitored remotely using an IoT system. These values will be sent to the operator's smartphone to determine when it's time to refill the waste oil fuel tank.



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# PREFACE

The 1st International Conference on Applied Sciences and Smart Technologies (InCASST 2023) has been organized by the Faculty of Science and Technology, Sanata Dharma University, Yogyakarta, Indonesia. This event was held on October 18–19, 2023, in Yogyakarta, Indonesia. As an effort to contribute in distributing research outcomes, especially in the search for renewable and clean energy, waste management, environmental management, and sustainable agriculture. InCASST 2023 presented four honorable international keynote speakers from representative countries: 1) Prof. Tokuro Matsuo, Advanced Institute of Industrial Technology - Japan; 2) Prof. Ir. Sudi Mungkasi, Ph.D., Sanata Dharma University-Indonesia; 3) Assoc. Prof. Dr. Peerapong Uthansakul, Suranaree University of Technology – Thailand, and 4) Assist. Prof. Dr. Eng. Rando Tungga Dewa, The Republic of Indonesia Defense University-Indonesia. This event selected local researchers and overseas fellows to share their best research works at this conference to reach a broader network of researchers. After a rigorous selection process, the Scientific & Editorial Board decided to publish 46 papers in E3S Web of Conferences, open-access proceedings in environment, energy, and earth sciences, managed by EDP Sciences, and indexed on Scopus, Scimago.

The published papers have passed all necessary improvement requirements following the Web of Conferences standard, reviewer's comments, and similarity tests by the Turnitin program. We want to thank the official committee, scientific & editorial boards, and organizing partners. Thanks to our co-host partners, Universitas Katolik Widya Mandala Surabaya, Universitas Prasetya Mulya, and Institut Teknologi Nasional Yogyakarta, for trusting and supporting this conference. Finally, we would like to briefly thank all presenters and attendees for their participation in sharing wonderful ideas and making creative decisions to inspire further research and exchange scientific reasons. We hope this time, all papers can be compiled into scientific works as the first publication of the 2023 InCASST. Lastly, we hope this conference encourages further research collaboration and see you at the next conference.

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# Utilization of used oil waste for boiler energy source

*Akbar* Pribadi[1], *Theresia Prima Ari* Setiyani[1], Tjendro[1], *Budi* Setyahandana[1], and Martanto[1*]

[1]Dept of Electrical Engineering, Sanata Dharma University, Yogyakarta, Indonesia

**Abstract.** Oil is one type of lubricating oil whose usage is increasing every year. The increase in oil usage automatically leads to an increase in waste generated. Used oil waste falls into the category of hazardous and toxic waste that requires special handling and processing. Used oil waste can be utilized as a valuable energy source with high economic value. The used oil waste to be utilized in this research serves as an energy source for the boiler. This research will consist of three main plant components: the Burner, plasma burner, and boiler. The used oil waste will be used as the primary fuel without any mixture for combustion. The waste oil will be heated in a spiral pipe to reach its boiling point, generating combustible gas steam. This flame energy source will be processed in the plasma burner to increase the flame pressure for boiler combustion. Control of the burner tank will be automated, making it easier for operators to manage the availability of burner fuel. Sensors will read the levels in burner tanks 1 and 2 to control the on-off operation of the oil pump. The values obtained by the sensor will be displayed on an LCD screen and can be monitored remotely using an IoT system. These values will be sent to the operator's smartphone to determine when it's time to refill the waste oil fuel tank.

## 1 Introduction

The rapid and sophisticated advancement of technology continues to unfold in the present era. This swift technological progress enhances human tasks to become more efficient and effective. These technological strides heavily rely on electrical energy, necessitating an increasing demand for electrical power over time. Poor management and careless disposal of used Lube oil can affect the environment negatively [1]. As reported by UN (2016), about six million deaths resulted from air pollution yearly. The burning of the waste lubricant contributes to the aerosol or green houses in the environment. Scientists have reported that in some geographical region e.g. West Africa, the dispersion of the air pollutants could travel at a speed of 10 -12 m/s [2]. The implication of this report is that air pollution from the burning of waste lubricant is not localized to the source of pollution but could travel with time to other locations. Hazardous waste, especially used oil waste, stands as the most commonly encountered liquid waste within Indonesian industries.

* Corresponding author: martanto@usd.ac.id

The consumption of lubricating oil (oil) in Indonesia, both for automotive and industrial machinery, amounts to approximately 650 million liters annually, with an annual growth rate of 7 to 10%. Assuming that 20% of oil is burned or discarded during use, this results in an annual supply of used oil waste of around 520 million liters, equivalent to 1,420 kiloliters per day [3]. Fuel for stoves (burners) can encompass both liquid and solid forms. There are several burners that utilize alternative fuels such as biomass. The utilization of biomass burners can also serve as an alternative technology that can be harnessed for power generation [4]. However, the availability of used oil is easier and more convenient, making burners fueled by used oil more efficient. This issue drives the research toward replacing burner fuels with readily accessible and cost-effective used oil fuel. Quoting from the journal "Design and construction of a used oil-fueled burner", the burner is designed for easy periodic maintenance and better economic value due to the use of used oil as fuel, which is more accessible and cost-effective compared to conventional fuels like gasoline and LPG [5]. In this study, the oil will be pre-burned to reach its boiling point, resulting in high pressure for efficient combustion. The pump will automatically start when the sensor detects a level below 3 cm and stop when it reaches a level above 7 cm.

The combustion process of the oil in this journal is facilitated by a nozzle that is sprayed with the help of a compressor. As for the fuel requirement, it is manually inserted into the burner's tank. One liter of lubricating oil waste can contaminate millions of liters of fresh groundwater from underground sources. If lubricating oil waste spills on the ground, it will affect the groundwater and pose environmental hazards. This is because lubricating oil waste can lead to soil nutrient depletion [6]. The design of the stove is expected to have better economic value compared to commonly used fuels such as gasoline, liquefied petroleum gas (LPG), and others. Burning used lubricants through vaporization is aimed at generating emissions that are much cleaner. As a result, the produced smoke is minimal and does not disrupt the surrounding area. Additionally, the stove design should also be easy to maintain [7].

Based on the aforementioned issues, while the designed burner is effective, it still lacks in terms of manual operational aspects, specifically regarding the oil refilling process. Thus, the intended solution for the highlighted problems with the burner is to automate its control and enable remote monitoring. The tank's control will be executed by an ESP32 microprocessor, which will receive input values from a fuel level sensor. An ultrasonic sensor is employed to monitor the fuel level within the tank.

The sensor measures the fuel distance and triggers the fuel pump to activate when it reaches the lower limit, while stopping the pump when it reaches the upper limit.

## 2 Theoretical foundation

### 2.1 Used oil

Used oil is a lubricant that originates from the operation of industrial machinery and motor vehicles. Used oil is readily available as almost every part of a machine utilizes oil to lubricate the components for smooth operation. Used oil has a different color and viscosity compared to new oil due to the heating it undergoes while serving as a lubricant. Used oil will have a distinct composition from unused new oil, as it becomes mixed with particles and contaminants present within the machinery [8]. The limited utilization, when compared to the availability or the rate of accumulation of used oil in the general population, would be considered quite minimal [9].

## 2.2 Burner

A burner is a device utilized to generate a flame for heating an object using various types of fuel, including gas, liquid, and solid substances. Burners come in diverse forms and utilize different types of fuel. In this research, the burner employs liquid fuel, specifically waste oil from motor vehicles. The utilized burner employs copper pipes to channel the used oil, which serves as the fuel for the burner. The waste oil, when heated in the copper pipes, attains high pressure and becomes easily combustible by the flame. Initially, the waste oil is ignited using alcohol (spirit) during the heating process until it reaches a temperature of 100-120ºC. To achieve complete combustion, the burner requires air to be mixed with the fuel [10].

## 2.3 On-Off controller

The On-Off control system is the most widely used control system in industrial processes and everyday applications. This system is very common due to its simple topology. The principle involves comparing the measured quantity with a reference value [11]. The output of this control has only two states: on and off. These states are used in many automated systems as regulators. One example is the on-off control system with hysteresis.

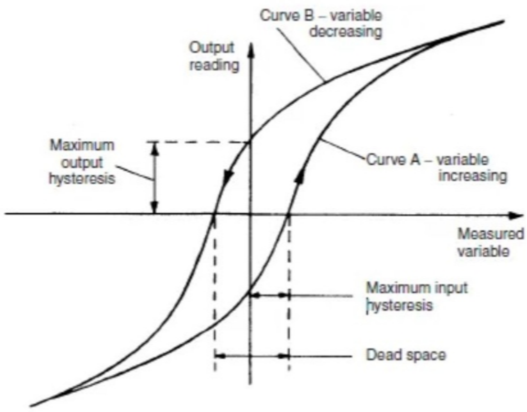


**Fig. 1.** Hysteresis curve [11].

Hysteresis is a system with memory, where the system remembers the initial state to return to it. Essentially, the hysteresis system will maintain the process condition within a predetermined working range. The set point will be defined as the maximum limit, and once this limit is reached, the system will return to its initial state. Figure 1 illustrates the hysteresis effect.

## 2.4 Ultrasonic sensor

An ultrasonic sensor operates based on the principle of sound wave reflection and is used to detect the presence of an object in front of it. Its operating frequency is in the range above the audible sound waves, typically from 40 kHz to 400 kHz. An ultrasonic sensor consists of two units: the transmitter unit and the receiver unit. The structure of both the transmitter and receiver units is quite simple, involving a piezoelectric crystal connected with an anchor mechanism and linked to a vibrating diaphragm. An alternating voltage with a working frequency of 40 kHz – 400 kHz is applied to a metal plate.

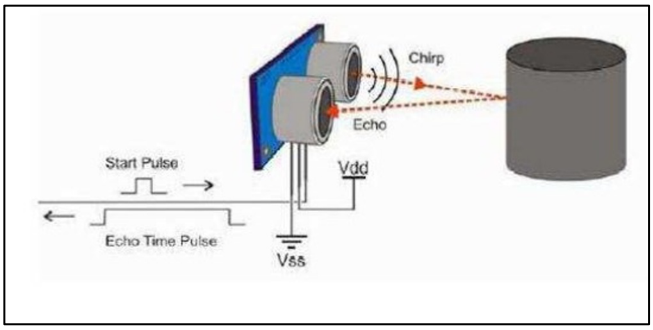


**Fig. 2.** Working principle of ultrasonic sensor.

The atomic structure of the piezoelectric crystal will contract, expand, or change in response to the polarity of the applied voltage, a phenomenon known as the piezoelectric effect [12]. In the pulse in function, it generates a time span of transition from low to high on the echo pin, and this duration is stored as a variable. The working principle and module of this ultrasonic sensor can be seen in Figure 2.

## 3 Research methods

### 3.1 Tools and materials

The tool used in this study is a burner stove that has been designed as depicted in Figure 3.

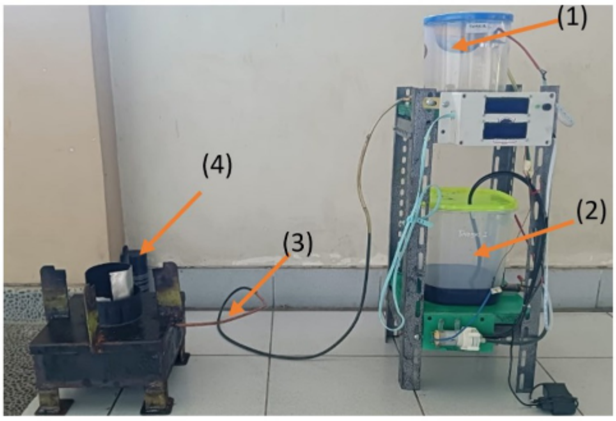


**Fig. 3.** Used oil fire burner.

Figure 3 illustrates the design of a burner stove apparatus that utilizes waste oil as fuel. The total fuel tank capacity is 6 liters. The operational principle of the aforementioned burner stove is as follows: ensuring that the fuel tank (1) is filled up to its maximum limit, and the fuel tank gets filled with oil that has been collected in the fuel collection tank (2). The used oil from the fuel tank flows towards the copper pipe through a hose connected to the copper pipe (3), subsequently being heated in the burner furnace (4) to reach the oil's boiling point and attain high pressure. The material employed in this study is used oil obtained from motor vehicle repair shops.

**Fig. 4.** Spiral furnace

In Figure 4, there is a depiction of a spiral burner inside the stove. This burner consists of 5 coils that the used oil will pass through. The used oil to be utilized will flow through the spiral burner so that upon reaching the end of the pipe, the used oil is already boiling and easily combustible [13].

### 3.2 Viscosity testing of used oil

The conducted testing aims to determine the viscosity magnitude (thickness) of the 4 samples used in the fuel.

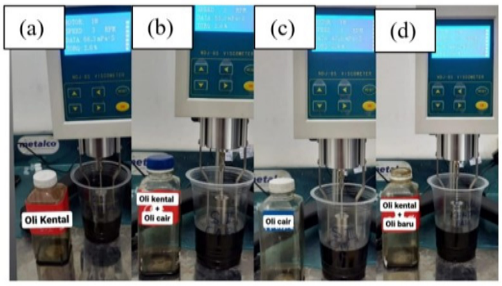


**Fig. 5.** Oil Sample (a) Used thick oil, (b) Used thick oil mixed with used liquid oil, (c) Used liquid oil, (d) Used thick oil mixed with new oil.

In Figure 5, a test is conducted to determine the viscosity of used oils (viscosity). The test is performed on 4 samples of used oil, Used thick oil (a), Used thick oil mixed with used liquid oil (b), Used liquid oil (c), and Used thick oil mixed with new oil (d). This viscosity test employs the Brookfield NDJ-8S Viscometer.

**Table 1.** Used Oil Viscosity test values.

| Oil Type | Viscosity Value (cps) |
|---|---|
| Used thick oil | 56.3 |
| Used thick oil mixed with used liquid oil | 52.2 |
| Used liquid oil | 47.6 |
| Used thick oil mixed with new oil | 44.2 |

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Table 1 displays the viscosity values of each used oil sample. A higher viscosity value indicates a thicker oil consistency. These viscosity values serve as differentiators among the 4 tested samples during the combustion process using a burner stove. The viscosity testing is conducted using the Brookfield viscometer on the thick oil sample, which has a viscosity value of 56.3 cps. This test is carried out using a 100 mL sample of the oil to measure its viscosity.

The viscosity measurement for the liquid oil is conducted using the Brookfield viscometer, which has a viscosity value of 47.6 cps. The viscosity testing is also performed on the used thick oil sample mixed with the used liquid oil. The test results in a viscosity value of 52.2 cps for that particular oil sample. Furthermore, the viscosity test is performed on the used thick oil sample mixed with new, unused motor oil. The obtained viscosity value is 44.2 cps, making this mixed oil sample the one with the lowest viscosity value among all the oil samples tested [14].

### 3.3 Start-Up process of the burner

The start-up process of the burner combustion system begins by opening the fuel valve located on fuel tank 2. Then, the combustion process is initiated by using alcohol to heat the oil on the spiral burner, causing it to boil and ignite. Once the oil on the spiral burner is ignited, it attains high pressure, making it easy to combust [15]. The burnt oil will continuously ignite the incoming oil from the fuel tank on the spiral burner.

**Fig. 6.** Flame during burner testing.

The initial combustion process of heating the oil on the spiral burner to boiling point takes approximately 5 minutes until the oil boils and reaches high pressure [5]. The viscosity (thickness) of the oil has an impact on the stability of the flame size on the burner stove, as shown in Figure 6. The flame height is around 24 cm - 26 cm when in a stable condition, yet the flame remains orange in color.

The process of extinguishing the flame on the burner stove takes approximately 10 minutes. The shutdown process starts by closing the valve on the fuel tank. After the valve is closed, the remaining oil on the spiral burner will be consumed first until it loses pressure. Once the fuel oil valve is turned off and the oil on the spiral burner is depleted, the flame will gradually decrease in size and eventually extinguish completely.

### 3.4 Testing the influence of fuel tank position

At this stage, combustion experiments are conducted by comparing 3 positions of the fuel tank. As shown in Table 2, the average volume and fuel oil flow rate are nearly the same.

**Fig. 7.** High fuel tank position

Figure 7, shows the first experimental position where the fuel tank is raised approximately 45 cm from the normal fuel position.

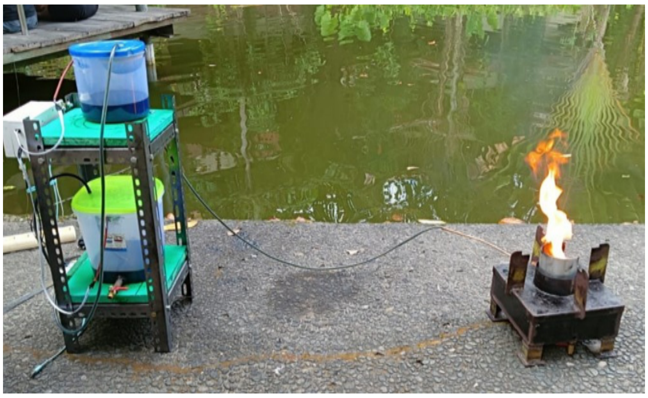

**Fig. 8.** Normal fuel tank position.

**Fig. 9. Flat fuel tank position**

Figure 8 shows the normal position of the fuel tank on the burner stove, which is 58 cm. Then, Figure 9 represents the flat position between the valve on the fuel tank and the burner stove. The position of the fuel tank does not significantly affect the fuel flow rate used in the combustion process.

**Table 2.** Influence of fuel tank position.

| No | High position (103 cm) | Normal position (58 cm) | Flat position (18 cm) |
|---|---|---|---|
| | Volume (L) | Volume (L) | Volume (L) |
| 1 | 0,035325 | 0,088313 | 0,017662 |
| 2 | 0,017662 | 0,07065 | 0,035325 |
| 3 | 0,07065 | 0,07065 | 0,052988 |
| Volume (L) | 0,041213 | 0,076538 | 0,035325 |
| Debit (mL/s) | 0,045792 | 0,085042 | 0,03925 |

By examining the table data, it can be concluded that the position of the fuel tank does not significantly affect the fuel oil flow rate used.

## 4 Results

After conducting the burner combustion testing experiment using 4 different fuel samples, the experiment was carried out for 5 hours to determine the combustion volume and rate on the burner. Table 3 represents the data results from the 4 tested samples.

**Table 3.** Combustion capacity.

| Combustion Capacity | | | |
|---|---|---|---|
| Oil Type | Average oil volume/15 min (L) | Burn rate (L/h) | Combustion Time / Liter (hours) |
| Used thick oil | 0,06 | 0,24 | 4,2 |
| Used thick oil mixed with used liquid oil | 0,08 | 0,32 | 3,1 |
| Used liquid oil | 0,06 | 0,24 | 4,2 |
| Used thick oil mixed with new oil | 0,09 | 0,36 | 2,8 |

Table 3 contains data on the oil combustion capacity during burning. In the table, you can observe how many hours of burner operation 1 liter of oil can provide. In these data, the amount of oil used is influenced by the viscosity (thickness) of the oil used as fuel.

**Table 3.** Boiling time comparison.

| Combustion Type | Time to Reach the Boiling Point of Water (minutes) |
|---|---|
| Gas Stove | 12,43 |
| Used thick oil | 24,05 |
| Used thick oil mixed with used liquid oil | 18,32 |

| | |
|---|---|
| Used liquid oil | 22,21 |
| Used thick oil mixed with new oil | 17,43 |

In the above data, 5 combustion trials were conducted using a gas stove, used thick oil, used liquid oil, a mixture of used thick oil and liquid oil, and a mixture of used thick oil with new motor oil. This experiment was carried out to determine the energy comparison between the flame produced by the burner and the flame generated by the gas stove. The burner stove produces a flame height ranging from 24 cm to 26 cm, with an orange color, resulting in a longer boiling time compared to the gas stove, as evident from Table 3. Burning using a gas stove has the fastest boiling time among other energy sources. However, utilizing a used oil burner stove can be more cost-effective and use cheaper fuel.

**Fig. 10.** Residue of used oil impurities

In Figure 10, there is the residue of oil produced after combustion. Poor-quality oil with high viscosity (thickness) will result in accumulated deposits that can clog the oil outlet holes. Oil with low viscosity (thickness) will last longer and produce a larger flame.

**Table 4.** Results of testing the success of on-off control for thick oil pump.

| **Fuel Tank** | | | | |
|---|---|---|---|---|
| **No** | **Time** | **Pump Condition** | **Sensor Height (cm)** | **Actual Height (cm)** |
| 1 | 09.05 | Off | 5 | 4,7 |
| 2 | 09.20 | Off | 4 | 4,2 |
| 3 | 09.35 | Off | 3 | 3,3 |
| 4 | 09.50 | Off | 3 | 2,9 |
| | 09.54 | On | 2 | - |
| | 09.55 | On | 3 | - |
| | 09.56 | On | 3 | - |
| | 09.57 | On | 4 | - |
| | 09.58 | On | 4 | - |

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| | | | | |
|---|---|---|---|---|
| | 09.59 | On | 6 | - |
| | 10.00 | On | 6 | - |
| | 10.01 | On | 7 | - |
| 5 | 10.05 | Off | 8 | 7,9 |
| 6 | 10.20 | Off | 7 | 7,4 |
| 7 | 10.35 | Off | 7 | 7,1 |
| 8 | 10.50 | Off | 7 | 6,7 |
| 9 | 11.05 | Off | 6 | 6,3 |
| 10 | 11.20 | Off | 6 | 5,6 |

This section will present the on-off control of the pump on a sample of thick used oil. The testing was conducted by measuring the availability of fuel tank contents during the combustion process. In Table 5, it can be observed that the thick oil requires 7 minutes to fill the tank from the lower limit to the upper limit.


**Fig. 11.** Fuel measurement.

The prolonged filling is due to the high viscosity of the thick oil, making it difficult for the pump to suction the oil. The pump will activate when the sensor value reaches the lower limit, which is when it falls below 3 cm, and it will stop when the sensor value touches the upper limit, which is more than 7 cm. Figure 11 depicts the implementation of an ultrasonic sensor measurement, manual measurement using a measuring instrument, and the measurement data displayed on the Blynk application.

**Table 5.** Results of testing the success of on-off control for liquid oil pump.

| **Fuel Tank** | | | | |
|---|---|---|---|---|
| **No** | **Time** | **Pump Condition** | **Sensor Height (cm)** | **Actual Height (cm)** |
| 1 | 10.01 | Off | 6 | 6 |
| 2 | 10.16 | Off | 5 | 4,7 |
| 3 | 10.31 | Off | 5 | 4,2 |

| | | | | |
|---|---|---|---|---|
| 4 | 10.46 | Off | 4 | 3,8 |
| 5 | 11.01 | Off | 3 | 3,4 |
| 6 | 11.16 | Off | 3 | 3,1 |
| 7 | 11.31 | Off | 3 | 3,8 |
| 8 | 11.46 | Off | 3 | 2,6 |
| 9 | 12.01 | Off | 2 | 2 |
| | 12.02 | On | 4 | - |
| | 12.03 | On | 6 | - |
| | 12.04 | On | 7 | - |
| 10 | 12.16 | Off | 9 | 8,7 |

This section will present the results of the on-off pump control on a sample of liquid-used oil. Similar to the previous process, measurements were conducted by assessing the availability of used oil in the fuel tank being burned. Table 6 indicates that liquid-used oil has a faster time to fill the fuel tank from the lower limit to the upper limit. This is due to the oil's lower viscosity compared to the previous oil, making it easier for the pump to suction the oil.


**Fig. 12.** Fuel measurement.

The liquid oil requires 4 minutes to fill the tank completely. In this experiment, the liquid oil proves to be more efficient compared to the thick oil, as it burns with a faster flow and does not generate black soot. The pump will activate when the sensor value reaches the lower limit, which is when it falls below 3 cm, and it will stop when the sensor value touches the upper limit, which is more than 7 cm. Figure 12 represents the implementation of an ultrasonic sensor measurement, manual measurement using a measuring instrument, and the measurement data displayed on the Blynk application.


**Fig. 13.** Graphical user interface.

In this IoT monitoring implementation, the Blynk application is utilized. Blynk will establish a connection with the ESP32 through a WiFi internet connection. The Blynk interface comprises 5 widgets to display the remaining fuel data. There are 2 gauge widgets designed to provide easy visualization of the tank's condition, indicating whether it's empty or full. The label widget is employed to display text indicating the tank's remaining content and whether the storage tank has sufficient content or requires immediate refilling, as shown in Figure 13.

## 5 Conclusions

The conclusion drawn from the research is that the utilization of used oil as a fuel is a relatively straightforward and beneficial practice. Unused used oil can have a high economic value after being wisely repurposed. The flame produced in the burner does not emit a significant amount of smoke, thus it does not pollute the surrounding air. Monitoring through the IoT system runs smoothly and can display real-time data results. Oils with lower viscosity are preferable for use compared to oils with higher viscosity. Fuel tank height does not significantly affect combustion intensity.

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