Prototype of Fuel Liquid Level Monitoring System at Gas Station Hidden Tank Using *the Internet of Things* (IoT)

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***Abstract*—** Currently, the availability of fuel oil (BBM) to the community is critical. One way to anticipate delays in supply and empty fuel stocks at refueling stations (petrol stations) is to periodically monitor the fuel liquid level with a Stick Sounding Meter measuring device dipped in the bottom of the tank. Monitoring uses the Internet of Things (IoT) concept, which can integrate surveillance system devices with the Internet network. The system uses an ultrasonic sensor mounted horizontally on the tank's liquid surface to detect the fluid level's distance and an ESP32 NodeMCU to communicate with ThingSpeak, an IoT device. If the tank's liquid exceeds 20% of its capacity, the test results will be displayed in real-time onThingSpeak, and a notification will be sent to the field. Therefore, both petrol station officers in the field and admins can monitor more efficiently. Ultrasonic sensor tests, data transmission accuracy, and fuel liquid levels are some of the stages carried out. Tank 1 has an accuracy rate of 97.066%, and Tank 2 has an accuracy rate of 95.451%.
Keywords* — *Monitoring, Liquid Level, Ultrasonic Sensor, NodeMCU ESP8266, Hidden Tank

I. Introduction

Fuel oil, or BBM, is one of the products of oil and natural gas natural resources that have been processed from crude oil or the earth. Petroleum itself is a complex mixture of various hydrocarbons, and Article 3 of Law Number 22 of 2001 on Oil and Gas states:

"The implementation of oil and gas business activities aims to, among other things, ensure the efficiency and effectiveness of the availability of oil and gas both as an energy source and as a raw material for domestic needs and the implementation and control of processing, transportation, storage, and trade businesses in an accountable manner."

In Article 8, paragraph (2) states that,

"The Government is obliged to ensure the availability and smooth distribution of Fuel Oil, which is a vital commodity and controls the livelihood of many people throughout the territory of the Republic of Indonesia. For this reason, the Government is obliged to ensure that there is always a sufficient amount of National Fuel reserves available for a certain period." [1]

Each petrol station has a hidden tank, also known as an underground tank, which stores fuel oil (BBM) such as Pertalite, Pertamax, Dexlite, and Solar [2]. An example is the 53.672.22 petrol station on Jl. Soekarno Hatta No. 102, Probolinggo City, has five latent stainless steel tanks with a capacity of 30 KL (3 units) and 20 KL (2 units). This latent tank must be placed in an underground excavation pit, and the cover or compartment must be surrounded by concrete with a thickness of at least 150 mm. The latent tank and its compartment must be marked to distinguish it from other fuel tanks.

Due to their underground position, almost all petrol stations in Probolinggo City, as shown in the survey, still use the manual method to check fuel stocks. To do so, the measuring device *Stick Sounding Meter is* immersed in a hidden tank, and the boundary between the sections *of the Stick Sounding Meter*, which is dyed with fuel, is used as an indicator of the fuel level in the hidden tank.

Because it allows delays in fuel delivery to petrol stations and considering the increasing fuel needs of the community, it is very important to know the fuel stock at these petrol stations. A system is needed to monitor fuel at petrol stations to find out the actual fuel stock. Systems for monitoring liquid levels in tanks have been developed in several previous studies. Ultrasonic wave technology, SMS gateway, Blynk app, microcontroller-based ESP32 NodeMCU WiFi module, and IoT concept are all components used in the design of this system. One example is a study conducted by Hadi Septia Sendi in 2018 on how to create a system to track the amount of oil remaining in underground tanks. The oil volume measurement was carried out using the Arduino UNO microcontroller as the control center, and the results were displayed on a 16x2 character LCD and buzzer.

The study conducted by Nuril Alawi and Indah Sulistiyowati used an ultrasonic sensor HC-SR04 to measure fuel levels in gas station reservoirs based on IoT. The Blynk application can display measurement results [3]. In their research on calculating the volume of latent fuel tanks using the Circle and Tembereng Area Method, Tianur et al. displayed the latent tank oil volume parameters on a web page. They sent a warning when the tank level was low. Because the readings of the instrument cannot be accessed remotely, this study has a weakness [4].

This research focuses on IoT, one of the most developed technologies in the industrial revolution 4.0. IoT allows every object it has to connect to the internet so that they can control it remotely via *a smartphone* or even voice commands. IoT at petrol stations is considered quite effective because petrol station officers or the nearest Pertamina can use the IoT monitoring system on hidden tanks to determine whether the gasoline stock is still sufficient or has run low [5][6]. In addition, the system can send signals to nearby depots to deliver additional supplies. As a result, Pertamina will immediately send fuel oil (BBM) supplies to the ordering petrol stations.

Ultrasonic sensors and Arduino IDEs are used to process the data; The ESP32 NodeMCU is used to communicate with supporting IoT applications such as *ThingSpeak* [7]. This system is intended to combine liquid measurement instruments in gas station reservoirs with Internet of Things (IoT)-based monitoring systems. The goal is to improve the efficiency and effectiveness of petrol station management. A tool to monitor the oil level in the gas station's hidden tank has been developed in this study. The tool can automatically measure and calculate the oil level in the tank and display that data on the web and Android app. In addition, if something goes wrong, the oil level in the tank is close to exhaustion or if the data output does not meet expectations.

The problem in this study is the transmission of data from the *Internet of Things* (IoT)-based prototype system to the web server and the accuracy of the ultrasonic sensor on the prototype system intended to monitor the level of fuel oil liquid in the gas station reservoir. This study aims to design a system that can inform the accuracy of data transmission from the prototype of the fuel oil level monitoring system in the gas station reservoir to *a web server based* on the *Internet of Things* (IoT) with a high level of accuracy.

This research can help petrol station officers accurately measure the fuel level in the latent tank and simplify the process of monitoring fuel availability in the latent tank. This is part of an effort to prevent fuel shortages at petrol stations and provide the best service to the community.

The design and application of the tools used in this study were limited by the following: ultrasonic sensors, one-way communication with a web server, prototype testing using water media instead of original fuel, and no backup power source.

II. Materials and Methods

The research plan in Figure 1 consists of a literature study, which is a series of actions that include reading, recording, and collecting data from the library, as well as managing research materials [8]. Tool design is divided into two stages: hardware and software. Furthermore, tool building is the creation of a prototype that can identify the fuel level in the latent tank and display the error in case of a problem. Data testing is conducted to determine how well the tool is made. Finally, Analysis and Evaluation: At this stage, the researcher analyzes the test results and evaluates the system to determine if it works as intended.

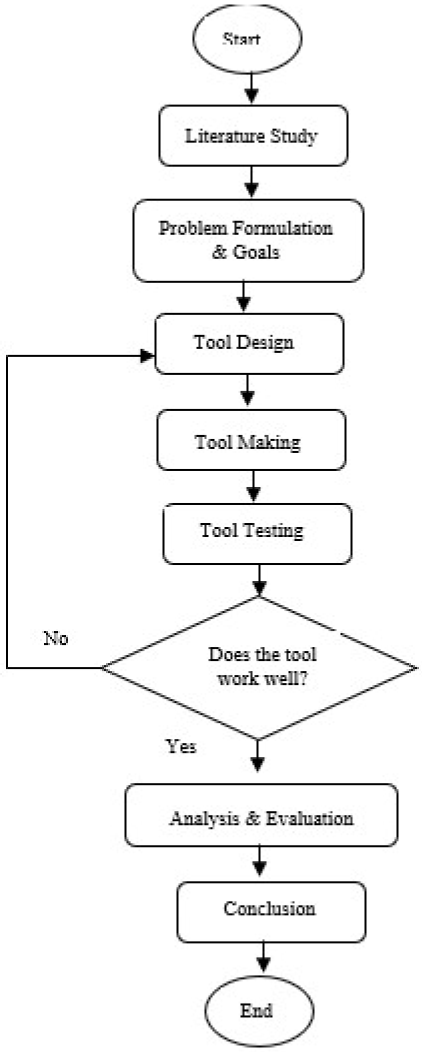


Figure 1. Research Flowchart
(Source: Personal Documents)

System Design Concept

The ESP32 microcontroller, equipped with a built-in *Wi-Fi* module, is used in this prototype. This research tool also uses the ultrasonic sensor HC-SR04 to measure fuel altitude through the reflection of an object against the sensor. These sensors work by *the time of flight method*, which means the time elapses between the ultrasonic waves sent by the transmitter and the echoes received by the receiver [9].

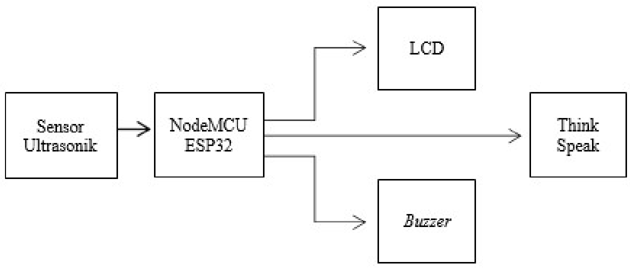


Figure 2. Block Diagram

The NodeMCU ESP32 measures the fuel's surface height using an ultrasonic sensor. Then, the processed data is sent to the LCD and *ThingSpeak* by the ESP32 NodeMCU. Meanwhile, the buzzer serves as an output and will be activated if a notification is watched until the receiver first receives the echo. The design concept of this system is shown in Figure 2.

Hardware Design

This hardware design created with the Fritzing application is shown in Figure 3. The purpose of hardware planning is to lay out the electronic networks used. The ESP32 NodeMCU, HC- SR04 Ultrasonic Sensor, Power Supply, Buzzer, and OLED LCD on the front are used as interfaces. The supply voltage is 3-5V DC. The ground pin on the ultrasonic sensor is connected to the ground pin of the nodeMCU as the source of the sensor's negative voltage. In contrast, the VCC pin on the sensor is connected with the 5V pin on the NodeMCU as the source of the sensor's positive voltage.

Here is the wiring hardware prototype of the tool:

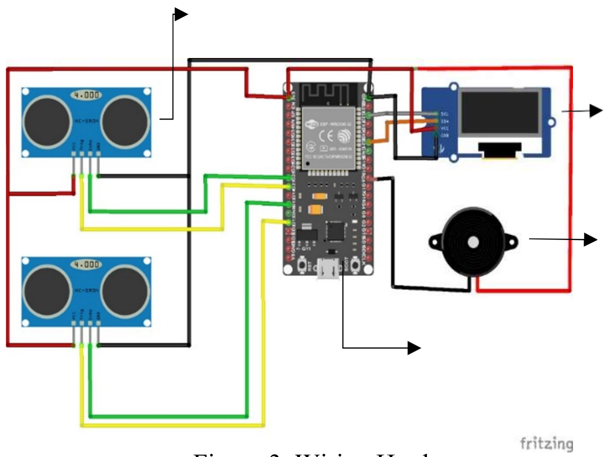


Figure 3. Wiring Hardware

Software *Design*

There are two stages in the design of this program. First, the NodeMCU ESP32 programming uses the Arduino IDE application to calculate the liquid volume value. This stage starts the system work process by connecting the ESP32 NodeMCU to the internet network, allowing software and hardware to communicate. Once connected, the data read by the sensor is immediately processed and sent to a web server on the *ThinkSpeak Website* [10].

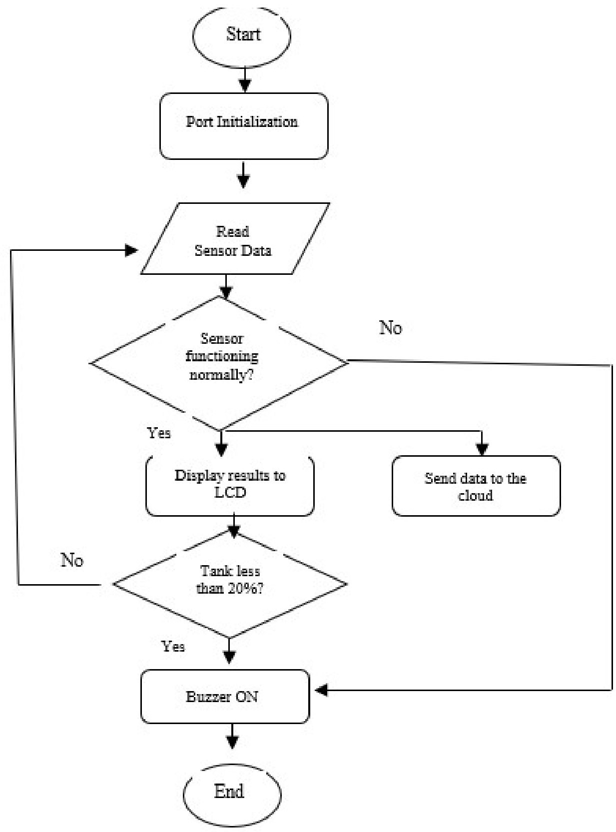


Figure 4. System Flowchart

Product Design

This is the product design of the research tool that the researcher will create. The design of this tool, as shown in Figure 5, was created using SOLIDWORKS.

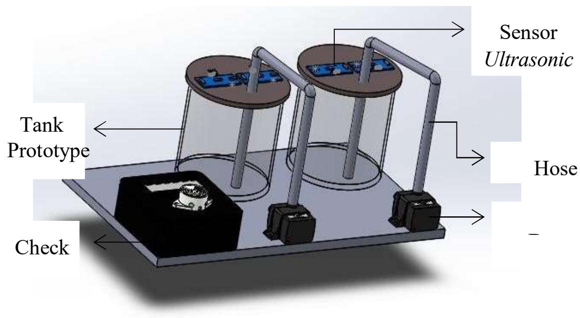


Figure 5. Tool Design

This tool measures 40 cm long and 40 cm wide. The prototype is simulated with two measuring cups of 3-liter volume. This research tool uses an adapter as a power source. At the top of the measuring cup, an ultrasonic sensor reflects waves to measure the distance between the liquid and the LCDs, which is the liquid volume value.

Overall System Testing

Testing is conducted to ascertain system errors and whether the tool can function properly.
1. Testing of ultrasonic sensor HC-SR04
2. Liquid level testing
3. Buzzer testing

4. Testing the accuracy of data transmission from *the reading sensor* to *the web server*

III. Results and Discussion

Product Design Results

After completing the design stage and selecting the components, the tool realization stage, which is the manufacture and assembly of the design that has been made, produces the following results:

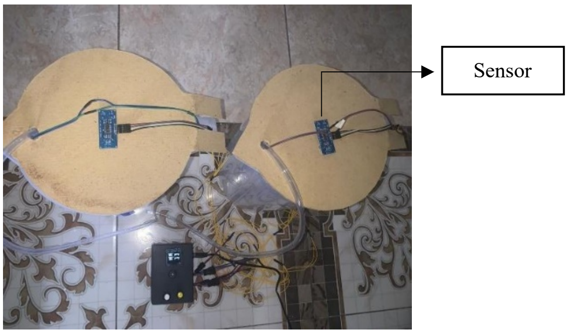


Figure 6. Top View Tool Design Results

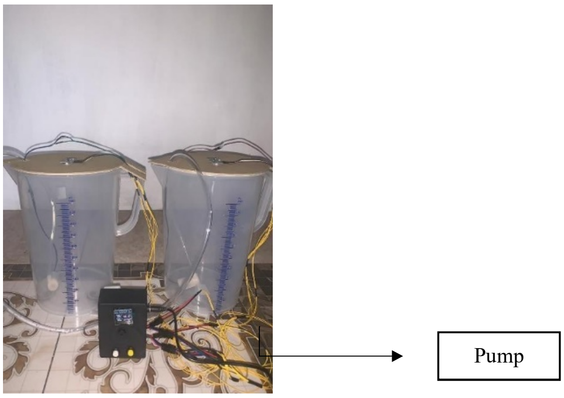


Figure 7. Side View Tool Design Results

Figure 6 shows that each tank or measuring cup has a single ultrasonic sensor and a pump that dispenses water from the tank. The sensor records the liquid level in the tank, which is then displayed on the LCD, as shown in Figure 7.

Mechanical Design Results

Mechanical manufacturing includes a 10 cm x 7.5 cm x 3.2 cm box to accommodate a minimal ESP32 system, buzzers, button buttons, and an OLED LCD displaying liquid volume values. The prototype uses two 5-liter volume measuring cups with an ultrasonic sensor at the top.

Hardware Design Results

The results of the *hardware* design can be seen in Figure 8 below.

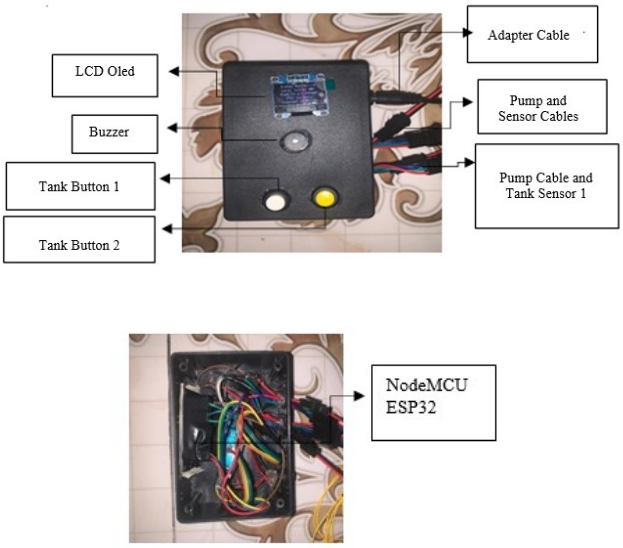


Figure 8. *System Flowchart*

HC-SR04 *Ultrasonic* Sensor Test Results

The ultrasonic sensor HC-SR04 needs to be tested using a standard measuring instrument to ensure its accuracy in water level measurement. The standard measuring tool used for comparison is the Bar. The error value of the ultrasonic sensor HC-SR04 can be known from the comparison results. Comparative data of the HC-SR04 Sensor with a standard measuring tool in the form of a Bar in Table 1.

Using an in-line barrier with the ultrasonic sensor as a reflecting object allows data acquisition on ultrasonic sensor testing. Until the machine is switched off (completed), the ultrasonic sensor will continue to provide distance data between the sensor and the reflecting object in decimal units of "cm." After that, the bar is used to compare the measurement results with the values obtained from various monitors. Figure 9 shows the ultrasonic sensor testing procedure.

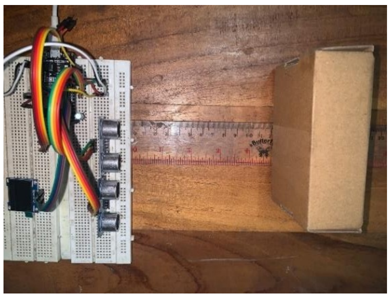


Figure 9. Sensor Testing

The experiment to	*Ultrasonic* Sensor HC-SR04 (cm)	Standard Measuring Instrument (cm)	Correction (cm)	*Error* (%)
1	2,95	3	0,05	1,667
2	4,89	5	0,11	2,200
3	6,5	7	0,5	7,143
4	8,8	9	0,2	2,222
5	10,5	11	0,5	4,545
6	12,86	13	0,14	1,077
7	14,9	15	0,1	0,667
8	16,55	17	0,45	2,647
9	18,45	19	0,55	2,895
10	20,37	21	0,63	3,000
Total Error				28,06
Rata-rata Error				2,806

Table 1. HC-SR04 Ultrasonic Sensor Test Results

To determine the accuracy value of the ultrasonic sensor and the reflective medium used in the form of a beam, Table 1 shows the results of testing the ultrasonic sensor with a standard measuring instrument (Mistar) as many as ten data at a distance of 3 to 21 cm using decimal numbers. Since the ultrasonic sensor has the minimum characteristics to detect a distance of 0.02 m or 2 cm, the test results show a less significant difference.

Liquid *Level* Test Results

In manufacturing this prototype, the tubular container has a bottom diameter of 15 cm, an upper diameter of 18 cm, and a height of 27 cm. The maximum height used in this study was 20.99 cm, so the value of the liquid volume had to be calculated first, and then the results would be converted into percentages. The sensor reads the fluid level to collect data and calculate the % error value. The tank volume used is only 4500 cm3 from the actual volume of 5000 cm3. This maximum volume ensures a safe distance between the cable and the tank. In this prototype, the minimum installation distance of underground high-voltage cables to the fuel storage tank is 1.5 m, so the ratio is 1/300 of the actual minimum installation distance. So the safe distance of cable installation on the prototype is ±5 cm with a maximum volume surface [11].

Figure 10. Liquid Surface Distance Display on Tank Read by Ultrasonic Sensor

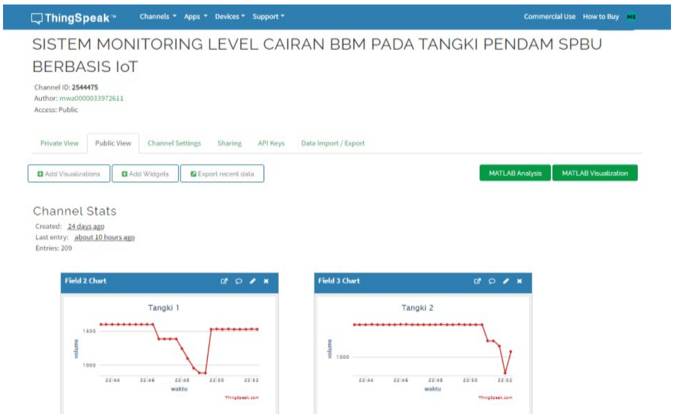


Figure 11. Display of Tank 1 and 2 Liquid Level Test Results in *ThingSpeak*

Table 2. Liquid Level Test Results (1)

No	Tangki 1			Tangki 2		
	Tinggi Permukaan Cairan (cm)	volume (ml)	*Level* Cairan (%)	Tinggi Permukaan Cairan (cm)	volume (ml)	*Level* Cairan (%)
1	4,88	4609	102,42	5,87	4508	100,18
2	6,8	4120	91,56	8,13	3932	87,38
3	9,1	3536	78,58	10,19	3409	75,76
4	10,8	3104	68,98	11,54	3064	68,09
5	13,16	2503	55,62	13,6	2540	56,44
6	15,2	1984	44,09	15,66	2017	44,82
7	17,44	1413	31,40	16,93	1694	37,64
8	19,04	1007	22,38	19,17	1123	24,96
9	21,27	440	9,78	21,4	556	12,36
10	24,23	0	0,00	24,08	0	0,00

Table 2. Liquid Level Test Results (2)

Tangki (Sebenarnya)			*Error Level* Cairan 1 (%)	*Error Level* Cairan 2 (%)
Tinggi Permukaan Cairan (cm)	volume (ml)	*Level* Cairan (%)		
20,998	4500	100	-2,422	-0,178
18,665	4000	88,89	-3,000	1,700
16,332	3500	77,78	-1,029	2,600
13,999	3000	66,67	-3,467	-2,133
11,666	2500	55,56	-0,120	-1,600
9,332	2000	44,44	0,800	-0,850
6,999	1500	33,33	5,800	-12,933
4,666	1000	22,22	-0,700	-12,300
2,333	500	11,11	12,000	-11,200
0,000	0	0,00	0,000	0,000

This buzzer test's purpose is to determine the buzzer's

Table 3. Buzzer Test Results

No	Time on the appliance screen	Time in *ThingSpeak*	Time difference (seconds)
1	10.13.41	10.13.41	0
2	10.13.46	Not Availabl e	Data Delivery Failed
3	10.13.55	Not Availabl e	Data Delivery Failed
4	10.14.06	10.14.06	0
5	10.14.16	Not Availabl e	Data Delivery Failed
6	10.14.26	10.14.26	0
7	10.14.36	Not Availabl e	Data Delivery Failed
8	10.14.46	10.14.46	0
9	10.14.56	Not Availabl e	Data Delivery Failed
10	10.15.06	10.15.07	0

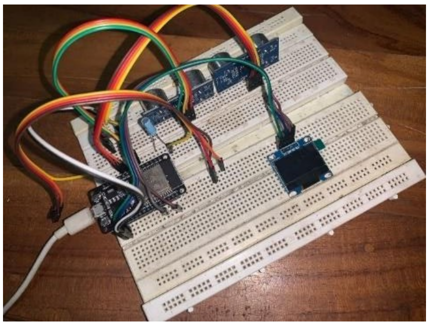


Figure 12. Data Delivery Accuracy Testing

function in the listing of programs created with the Arduino IDE. In this test, the buzzer will be on or ON if the sensor

detects a liquid level of less than 20% or the equivalent of 900 ml, and it will turn OFF if the liquid level is more than 20%. The buzzer test table is as follows:

Table 4. Liquid Level Test Results

Percobaan ke-	Level Cairan (ml)	Buzzer
1	100	ON
2	300	ON
3	500	ON
4	700	ON
5	900	ON
6	1100	OFF
7	1300	OFF
8	1500	OFF
9	1700	OFF
10	2000	OFF

Test Results of Data Transmission Accuracy from Sensor Reading to Web Server

To perform the test procedure, the data transmission from the NodeMCU to the web server is tested on the system to evaluate its performance. The NodeMCU is the access point on the transmitter side, and *the ThingSpeak* is the receiver side, which is already connected to the laptop. Programs created with the Arduino IDE Data are taken from the monitor serial (the time in the research tool) and the time displayed on the ThingSpeak server web screen. Then, the algorithm calculates the correction. In real-time, the data delivery accuracy value is sent to *ThingSpeak*. Testing starts on Friday, 10 May 2024, at 09:26:04 and ends at the end of the hour. The test assessed performance by collecting ten data sets during each delivery period, as shown in Table 5 and Table 6.

Table 5. Accuracy of data transmission every 15 seconds

No	Waktu di layar alat	Waktu di *ThingSpeak*	Selisih waktu (detik)
1	09.36.21	09.36.21	0
2	09.36.31	Tidak Tersedia	Pengiriman Data Gagal
3	09.36.46	09.36.46	0
4	09.37.01	09.37.01	0
5	09.37.16	Tidak Tersedia	Pengiriman Data Gagal
6	09.37.31	09.37.31	0
7	09.37.46	Tidak Tersedia	Pengiriman Data Gagal
8	09.38.01	09.38.01	0
9	09.38.16	Tidak Tersedia	Pengiriman Data Gagal
10	09.38.31	09.38.31	0

Table 6. Accuracy of data transmission every 19 seconds

No	Waktu di layar alat	Waktu di *ThingSpeak*	Selisih waktu (detik)
1	10.08.43	10.08.43	0
2	10.08.59	10.08.59	0
3	10.09.16	10.09.16	0
4	10.09.35	10.09.35	0
5	10.09.54	10.09.54	0
6	10.10.13	10.10.13	0
7	10.10.32	10.10.32	0
8	10.10.41	10.10.41	0
9	10.11.10	10.11.10	0
10	10.11.29	10.11.29	0

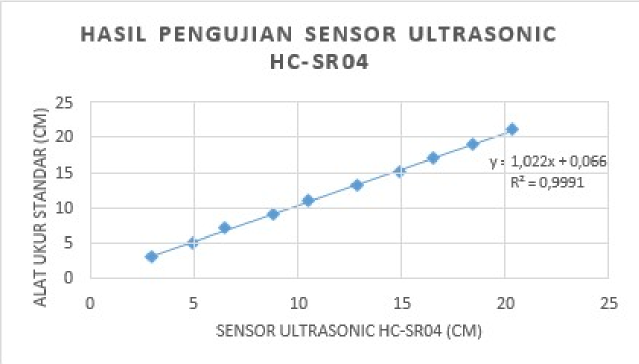


Figure 13. HC-SR04 Ultrasonic Sensor Testing

With the regression formula generated by the graph according to the calculation, namely:

$$y = 1.022x + 0.066 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$R2 = 99{,}91\%$$

The correlation coefficient indicates the direction, degree, and strength of the relationship between two variables, i.e. a standard measuring instrument and an ultrasonic sensor. The ultrasonic sensor HC-SR04 may be accurate because its value compared to a standard measuring instrument shows a linear graph in Figure 13. This is because the correlation coefficient is 0.9991. The data collected is more valid when it is closer to the value of 1.
Therefore, there is a relationship between the ultrasonic sensor (X) and the standard measuring instrument (Y) that meets the criteria of "very strong", meaning that there is a unidirectional (symmetrical) relationship between the standard measuring instrument (Y) and the ultrasonic sensor (X) of 99.91%, and an additional variable that affects the remaining 0.0879%.

Liquid *Level* Testing

This liquid level test measures the water level using a horizontally mounted ultrasonic sensor. The volume of water that can be accommodated corresponds to the volume of the measuring cup, which is 5 liters. However, to optimize operations and simulate the application of K3 in the SOP for Hidden Tank Location Planning, the minimum distance between the installation of the underground high-voltage cable line and the fuel storage tank is 1.5 m. Therefore, the required height is ±1.5 mm from the height of the measuring cup to achieve maximum volume.

Based on the results of the test in Table 2, an accuracy value can be obtained with the following calculations:

Average Value – average Tank 1 error = 0.786%

Average Value – Average Tank 2 error = 3.689%

Accuracy of 1= 100% – 0.786 % = 97.066%

Tank Accuracy 2 = 100% – 3,689 % = 95,451%

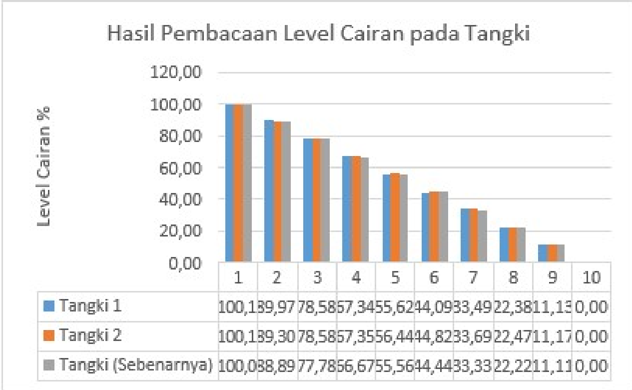


Figure 14. Percentage Chart of Liquid Level Readings

The test was carried out by taking ten data on two tanks at once. Due to the limited level of sensor accuracy, tank 1 has an average error result of 0.786%, and tank 2 has an average error result of 3.689% in the tank fluid volume measurement data at every 500 mm reduction.

Testing the accuracy of data transmission from sensor readings to web servers

Tables 5 and 6 show that the average difference in time for sending data from the research tool to *ThingSpeak* is 0 seconds. This table can be used to create the following charts.

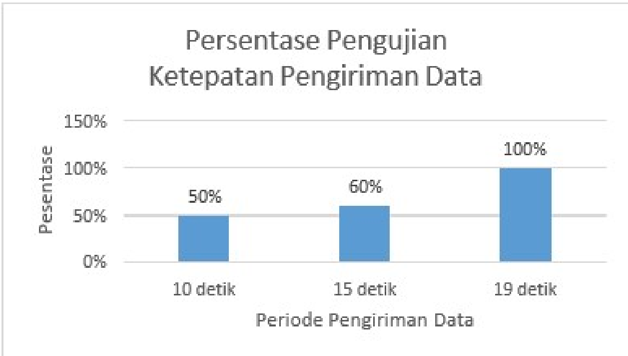
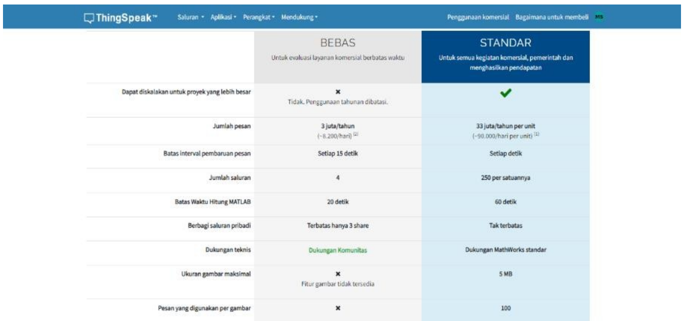


Figure 15. Results of Data Transmission Accuracy Test



Percentage

Figure 16. License Terms on *ThingSpeak*

The test was conducted by sending data to ThingSpeak three times, and the results showed some data errors. Notably, at 10- and 15-second intervals, ThingSpeak receives only 50% of the data; at 15-second intervals, 60% of the data is received; and at 19-second intervals, all data is received. This condition is affected by the features available in the free version of the ThingSpeak server. This feature limits the amount of data that can be sent and slows down data updates (only once every 15 seconds). As a result, if the delivery is made every 15 seconds or so, and the delivery time is at least 19 seconds for this test, the ThingSpeakplatform will receive more data.

Overall Testing

The overall system test's purpose is to ensure that the fuel level monitoring system on the fuel oil tank can operate as expected. Figures 6 and 7 show the results of the system design. Testing begins by applying a voltage to the prototype to activate the system. The input and output pins on the NodeMCU ESP8266 must be enabled with the Arduino IDE to start this process. Next, the NodeMCU ESP8266 connects the device to the Wi-Fi network.

Two tanks are used to simulate real conditions with two different fuel types. Ultrasonic sensors monitor the liquid level in the tank in real-time, and the pump reduces the water in it. Sensor data is sent to *the ThingSpeak* platform via a USB cable, which then connects to a Wi-Fi network to transmit signals or data from any sensors in the tank to the *ThingSpeak* platform. In addition, the data is displayed on the OLED LCD.

At this point, the test analysis is carried out by comparing the readings of the two systems with conventional measuring instruments such as glasses and meters. In the first test, the performance of the HC-SR04 Ultrasonic Sensor was evaluated to measure the distance or height of the liquid in the tank. Test results for tank level and volume are shown in Figure 9 and Table 1. The second test evaluates the performance of the liquid volume readings that have been converted to milliliters (ml) and the percentage accuracy of the fluid level readings by the sensors in the tank, shown in Figure 9.

As shown in Table 3, the third test aims to assess the performance of notifications in the form of buzzer sounds when the sensor detects a liquid volume of less than 20%. The final test focused on the accuracy of sending data from sensor readings displayed on the web server. Because this system uses real-time data delivery, it is necessary to anticipate delays to get the best results. Therefore, a strong internet connection is required to achieve this goal. The test results are shown in Figure 10 and Tables 4 to 6.

IV. Conclusion

Here is the conclusion:

1. The results of the ultrasonic sensor test showed an accuracy of 99.91%. These values indicate that the ultrasonic sensor provides accurate results.
2. ThingSpeak *data* is updated periodically if connected to the internet. This study takes at least 19 seconds to receive 100% of the data, without delay, because the internet connection is quite stable.
3. A prototype of a liquid-level monitoring system can be accessed through an Internet of Things (IoT) webserver called *ThingSpeak*. This appliance can emit a buzzer sound to indicate a liquid level of less than 20%.
4. The liquid level test in tank 1 showed a relative error result of 0.786% with an accuracy rate of 97.066%, while the liquid level test in tank 2 showed a relative error result of 3.689% with an accuracy rate of 95.451%. This shows that the error value is relatively small and the accuracy level is almost perfect.

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