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Liquefied Petroleum Gas (LPG) Leak Detection Mitigation System with MQ-6 Sensor based on the Internet of Things (IoT)

Dian Novitaningrum[1], Yuni Handayani[2], Taufik Hidayat[3]

[1,2,3]*Department of Informatics, Faculty of Computer and Design, Selamat Sri University, Kendal, 51351, Indonesia*

[1]*dnovitaningrum.uniss@gmail.com,* [2]*yuni0406handayani@gmail.com,* [3]*taufikhidayat.jc@gmail.com*

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CORRESPONDENCE

Phone : +6281325750267
E-mail: dnovitaningrum.uniss@gmail.com

ABSTRACT

The community is beginning to shift from the use of petroleum fuel to Liquefied Petroleum Gas (LPG). In 2023, the Kendal Regency Statistics Agency recorded 53 cases of fire. One of the factors contributing to these fires was gas cylinder leaks, which require preventive measures, education, and mitigation efforts for the proper use of LPG. This study was conducted by designing an LPG gas leak detection system based on the Internet of Things (IoT) using an MQ-6 sensor to notify users of emergencies. The system aims to notify users via the Blynk application to prevent gas leaks. The research method includes designing the device by assembling and testing components. Additionally, software was developed to connect the sensor to the notification application using Blynk. The system can detect LPG gas leaks within a range of 1–16 cm. A safe threshold is defined as gas levels < 40 ppm, while levels ≥ 45 ppm indicate a hazardous status. The conclusion from this research shows that the average gas concentration when the green LED is on is 33 ppm with a detection time of 0 seconds, the yellow LED at 40.6 ppm with a detection time of 11.6 seconds, and the red LED at 50 ppm with a detection time of 25.3 seconds, accompanied by a buzzer sounding as a warning of a gas leak in the LPG cylinder. Further research focused on improving the accuracy of the system connected to users WhatsApp accounts.

1. INTRODUCTION

The transformation of people's lifestyles is in line with changes in technology, such as the shift from using fuel oil (BBM) to liquefied petroleum gas (LPG) [1]. LPG is produced by PT. Pertamina (Persero) in 3 kg cylinders and is widely used by the community for industrial, commercial, and other household purposes [2]. The demand for LPG must be balanced with LPG subsidy allocations and economic growth in each region. In Kendal, the economic growth for gas procurement in 2023 is 7.20%, an increase from 6.21% in 2022, representing a rise of 0.99%. Data from the Kendal Trade, Cooperatives, and SMEs Department indicates that the actual number of gas cylinders procured in 2024 was 9,933,200 cylinders [3].

According to data from the Centre for Public Policy Studies (PUSKEPI), there have been 189 cases of explosions involving household gas cylinders since 2008–2010 [4]. According to data from the Central Statistics Agency, the largest number of criminal cases and violations in 2023 were caused by fires. There were 53 fire incidents in 2023. The cumulative total from 2018 to 2023 was 153 cases. One of the factors contributing to fires is carelessly discarded cigarette butts, electrical short circuits, and LPG cylinder leaks [5][6][7]. For example, LPG cylinder leaks can occur due to inadequate supervision and lack of education on proper LPG cylinder usage, leading to misuse and subsequent leaks [8][9][10]. This can result in fires, explosions, and financial losses [11][12]. A survey from a study found that 78% of 500 households using LPG cylinders did not have a proper detection system in place in case of a cylinder leak. This poses a high risk of LPG cylinder leaks.

In March 2025, an explosion destroyed three houses in Depok. According to the Head of the Depok Fire Department, the explosion was preceded by a gas leak [13]. This incident highlights the need for preventive measures and the need to educate the public on the importance of using IoT-based detection systems.

The objective of this study is to design a device that includes assembly steps, testing, software design, and measurement of the device for an IoT-based LPG gas leak detection system using the MQ-6 microcontroller. The limitations of this study include the use of ESP8266 and notifications using Blynk to alert users to prevent LPG gas fires or explosions, as well as the use of the MQ-6 sensor. The results of this study are expected to significantly help educate and warn the public about preventive measures to avoid leaks, explosions, or fires that may occur in LPG gas cylinders.

2. RELATED WORK

The author has used several related literature sources as references in conducting this research, including relevant research. Other studies also explain the comparison of the use of the three sensors, namely MQ-2, MQ-3, and MQ-5, based on Arduino, with treatment using the benefits of lighter gases. The research proposes an Internet of Things (IoT) based system that detects LPG gas leaks and monitors gas levels in cylinders. An MQ-2 sensor is used to detect gas leaks, while an additional sensor is used to measure the remaining gas capacity. The detection results are then sent in real time to the user's device via IoT connectivity and equipped with an alarm to provide an early warning. Therefore, by using this approach, the system not only functions as a tool to prevent leaks that could potentially cause fires but also helps users monitor the availability of LPG in their households [14]. This study explains that gas concentration affects the identification of the buzzer's sound response, which also affects the LED light's illumination. This is because the sensitivity levels of the sensors vary. From this study, the sensor showing the highest concentration was the MQ-3 sensor [15]

The MQ-6 sensor was selected due to its higher sensitivity to propane and butane compounds. Both compounds are components of LPG gas [16]. The MQ-6 sensor can detect gas concentrations ranging from 200 to 10,000 ppm. Another advantage of the MQ-6 sensor is its effectiveness in detecting evaporating gases. LPG has a low concentration level with high accuracy. Additionally, the response time of this sensor is faster than other sensors. Its operating system is also simple and only requires a voltage of 5 volts [17].

In previous studies, the delay process was calculated, with an average delay of 4.5705712 ms for the MQ-2 sensor and an average delay of 3.659004 ms for the MQ-6 sensor. Similar research also explains that the MQ-6 sensor's response time is faster, which is important for mitigating the risk of fire due to LPG gas leaks. The average response time recorded in previous research was 15-20 minutes, which would be required without an automated system [17]. Similar research was also conducted by[18], using the Wemos D1 R1 and MQ-2 sensors. A limitation of this study is that the researchers only provided notifications when an internet connection was available; if the user did not have an internet connection, they would not be able to detect a gas leak.

Previous research entitled 'Implementation of a Gas Leak Detection System Using MQ-6 Sensors' was able to detect leaks. Testing was conducted by measuring the sensor output voltage under various conditions, including distance and gas release rate variations. The experimental results showed that the MQ-6 sensor has a maximum effective reading distance of 18 cm with a response time of approximately 45.26 seconds. This system is designed as an early warning solution so that gas leaks can be anticipated before they cause serious damage [19].

The novelty of this research is the adoption of the advantages of the MQ-6 sensor, which has a higher sensitivity level to propane and butane compounds. The MQ-6 sensor can also detect gas concentrations ranging from 200 to 10,000 ppm and effectively detect evaporated gases. In addition, this sensor has a faster response time than other sensors. Its operating system is also simple and only requires a voltage of 5 volts. Thus, most of the research that has been conducted previously still focuses on basic detection in gas leak notification. The research conducted can improve safety in the use of LPG gas cylinders by users in various environments.

3. METHODOLOGY

This study uses a flow chart in the form of a circuit diagram for the LPG Gas Leak Detection Mitigation System. Figure 1 explains the overall research flow, namely:

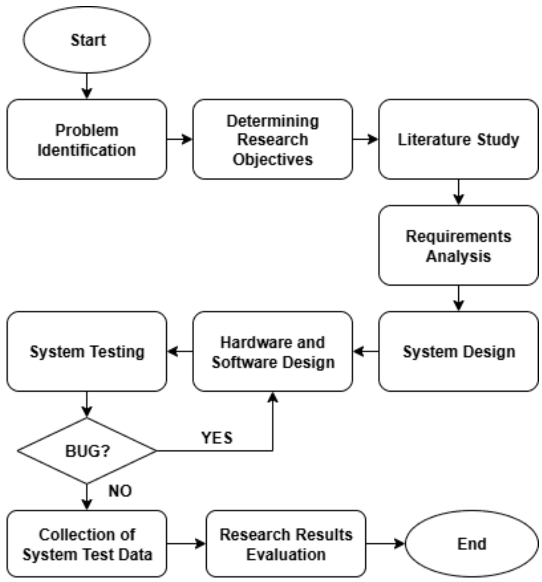

FIGURE 1. RESEARCH METHODOLOGY

In Figure 1, the Research Flow explains the process carried out by the researcher, starting from:

A. Problem Identification: The initial step in this method is where one of the factors contributing to frequent fires is LPG cylinder leakage.
B. Determining Research Objectives: In this method, to reduce the risk of LPG gas leakage, the researcher developed a system that can accurately detect gas leaks.
C. Literature Study: In this method, the researcher also conducted a literature study by reading reference journals relevant to the research topic.
D. Requirements Analysis: The next stage involves analyzing requirements.
E. System Design: After that, during the proposed timeframe, the researcher will create a system

design. The hardware and software design stages follow this.

F. Hardware and Software Design: In this method, the hardware that has been created is tested.

G. System Testing: The next method, the purpose of testing is to determine whether the system is running properly or if there are any bugs. If errors or bugs are found, the system will be repaired and tested again.

H. Collection of System Test Data: However, if there are no errors or bugs, the system will proceed directly to the data collection stage to obtain the results of the system testing that has been conducted.

I. Research Results Evaluation: Then, it will move on to the evaluation stage of the system's results. During the evaluation stage, if the system detects a LPG gas leak, it will generate an audio notification and change the LED light indicator from green to yellow, then red.

Figure 2 explains the system workflow diagram as follows:

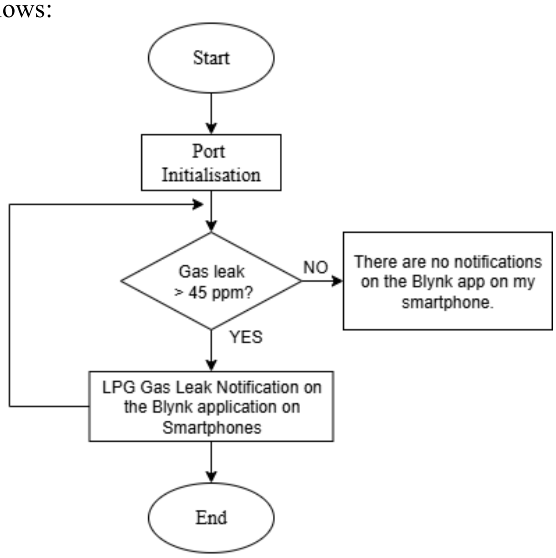

FIGURE 2. FLOWCHART OF SYSTEM WORKINGS

In Figure 2, the flowchart of how the system works, as developed by the researcher, begins with:

1. Port Initialization, which is the initial setup or configuration of the port on the microcontroller hardware.
2. MQ-6 Sensor, detecting LPG gas leaks if there is an LPG gas leak, a notification will be sent to the Blynk application with LPG gas leak range below 40 ppm.
3. If there is no leak, there will be no notification on the Blynk application.
4. The output is a notification of the LPG concentration that has leaked on the Blynk application on the smartphone.

The components used in this research include:

A. Internet of Things (IoT)

Internet of Things namely a physical network that has connections and can be uniquely identified, as well as being able to communicate, detect, and interact with its environment. The objects in question can exchange information in the form of data to provide automatic responses to events that have occurred and are used to make decisions without intervention [20]. The purpose of this IoT-based detection tool is to enable automatic changes that can be detected by sensors [21].

B. Liquified Petroleum Gas (LPG)

LPG is a mixture of natural gas consisting of various hydrocarbon elements. Its components consist of propane (C3H8) and butane (C4H10). Other contents include ethane (C2H6) and pentane (C5H12) [22]. In addition, there is mercaptan gas, which has a distinctive odor, making it easier to detect leaks in gas cylinders. One of the properties of LPG is (i) it spreads quickly and its liquid evaporates easily when released into the air, (ii) it is highly flammable, and (iii) the gas has a strong odor [23] [24].

C. Sensor MQ-6

The main function is to detect and measure the amount of gas. The MQ-6 sensor includes Digital Pins and Analogue Pins. The Digital Pin serves as an output to detect the presence or absence of gas in a specific area, so the output produced is only 1 or 0 [25]. Meanwhile, the Analogue Pin has an output in the form of an analogue signal whose value can change according to the concentration of gas measured, so it requires translation for the results. The MQ-6 can detect gas concentrations ranging from 100 ppm to 10,000 parts per million (ppm) [26]. Its main components include a micro ceramic tube made of AL203 material, a sensitive SnO2 layer, a measuring electrode, and a heating wire.

These components are enclosed in a mesh of iron and plastic. The sensor operates by changes in resistance caused by the heating wire when gas molecules reach a certain point and meet the sensitive SnO2 layer. When gas interacts with the layer, the resistance of the heating wire decreases in proportion to the gas concentration in the air. Conversely, if the gas concentration decreases, the resistance of the heating wire increases, thereby reducing the voltage at the sensor's output [16] [27] [28] [29]. Figure 3 illustrates the MQ-6 sensor:

FIGURE 3. SENSOR MQ-6

D. NodeMCU ESP8266

NodeMCU ESP8266 is a microcontroller application design integrated with ESP8266 and has Wi-Fi and TCP/IP capabilities. ESP8266 has many input and output pins that support additional sensors and modules. Its advantages make it suitable for gas leak detection systems and very easy to connect to the internet [30] [31]. Figure 4 illustrates the NodeMCU ESP8266, which is which is equipped with integrated Wi-Fi capability, flexible GPIO pins, and compatibility with various sensors, enabling efficient IoT data acquisition, real-time monitoring, and seamless cloud connectivity for lightweight embedded applications.

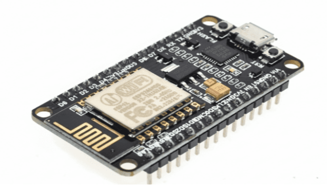

FIGURE 4. NODEMCU ESP8266

E. Breadboard

It is a series of electronic fields used to assemble the necessary components to create a perfect IoT circuit [30]. Figure 5 explains Breadboard, which is:

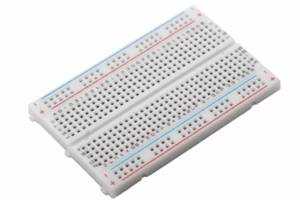

FIGURE 5. BREADBOARD

F. LED Light

Three LEDs were used: green, yellow, and red. The green LED indicates that the room is safe and the device is on. The red LED indicates that the indicator detects an excessively high LPG gas content [7], [32]. Figure 6 illustrates the LEDs as follows:

FIGURE 6. LED LIGHT

G. Resistor

As shown in Figure 7, a resistor is a component in a circuit that resists and regulates electric current. Its resistance is often referred to as resistance [30].

FIGURE 7. RESISTOR

H. Jumper Cable

It has the function of connecting one component to another [30]. Figure 8 illustrates the Jumper Cable as follows:

FIGURE 8. JUMPER CABLE

I. Buzzer

Figure 9 explains buzzers, electronic components that convert electrical signals into sound vibrations. They are commonly used as alarms in doorbells, clocks, and other warning devices [33][34][35][36].

FIGURE 9. BUZZER

J. Blynk

Figure 10 shows the application used to connect Blynk with NodeMCU ESP8266. It can also be used as an interface for projects implemented using drag-and-drop widgets [37] [38]. Blynk can also display warning notifications based on rules created by a smartphone.

FIGURE 10. BLYNK

K. Arduino IDE

Arduino Integrated Development Environment (IDE) is software for developing Arduino applications. This software can be downloaded for free from the website https://www.arduino.cc/en/software [39]. Figure 11 illustrates the Arduino IDE as follows:

FIGURE 11. ARDUINO IDE

4. Result and Discussion

The implementation of the tool designed in this study is shown in Figure 12 below:

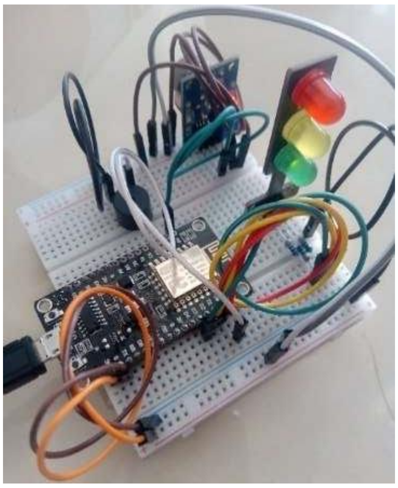

FIGURE 12. LPG GAS LEAK DETECTION DEVICE SERIES WITH MQ-6 SENSOR

Figure 12 shows a series of LPG gas leak detection devices consisting of a breadboard, jumper cables, LED lights (green, yellow and red), NodeMCU ESP8266, MQ-6 sensor, resistors and buzzers.

The device in Figure 12 operates by connecting the LPG gas leak detection device to the software, which uses Arduino IDE version 2.3.2 and the Blynk application to send notifications to LPG users.

The steps to use this LPG gas leak detection device are:

1. The MQ-6 sensor on this device detects leaks in the LPG gas cylinder,
2. The NodeMCU ESP8266 microcontroller processes the results of the detection performed by the MQ-6 sensor,
3. If the gas concentration detected by the MQ-6 sensor is below the safe limit of 40 ppm, the green LED light will turn on and the buzzer will not sound,
4. However, if the gas concentration detected by the MQ-6 sensor is above 41-44 ppm, the yellow LED light will turn on and the buzzer will not sound,
5. Meanwhile, if the gas concentration detected by the MQ-6 sensor is ≥ 45 ppm, the red LED light will turn on and the buzzer will sound.
6. The condition in Step 5 will be accompanied by the microcontroller sending the MQ-6 sensor detection results directly to the Blynk server via a Wi-Fi connection,
7. The LPG cylinder gas leak detection results will be displayed directly on the smartphone of the LPG user connected to the Blynk server.

Figure 13 illustrates a snippet of source code from the Arduino IDE programme.

```
#include <dummy.h>

#define BLYNK_PRINT Serial
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>

char auth[] ="TO0V81QtF17WTO2sf6oOPjLIuVVPwRLd";
char ssid[] = "Mahasiswa FKD";
char pass[] = "mahasiswa2024";
#define sensor A0
#define Buzzer 16
#define LED_Red 5
#define LED_Yellow 4
#define LED_Green 0

```

Figure 13. Arduino IDE Program Source Code Excerpt

Figure 13 illustrates the source code snippet used in this study. Figure 14 explains the Blynk application, stating that the detected gas level is 50 ppm. It also displays a graph of the LPG gas leak detection results.

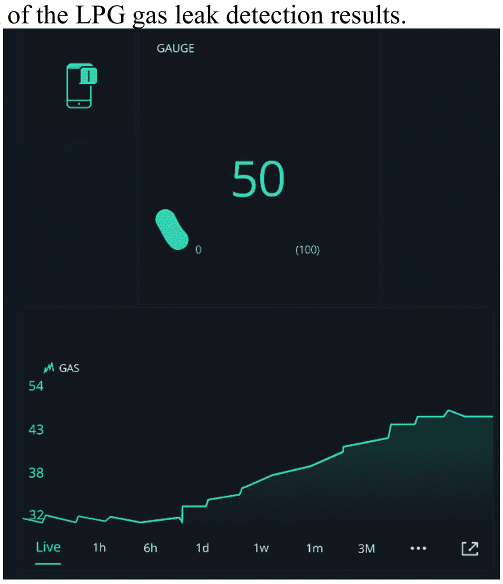

Figure 14. Blynk Application Display

This study explains that the threshold value for LPG gas leakage is considered hazardous when the gas concentration exceeds or equals 45 ppm. However, it is considered safe if the gas concentration is less than 40 ppm. The results are detailed in Table 1.

Table 1. Test Results for the Circuit when Sensor is Active

Minimum Limit of LPG (ppm)	Conditions	Buzzer
< 40	Save	Off
>= 45	Dangerous	On

Table 2 explains several indicators of safe conditions for LPG gas cylinders, including when the LED light is green, the buzzer is not sounding, and the regulator is closed.

Table 2. Safe Condition Gas Cylinder Has No Leaks

Indicator	Conditions
LED	Green light
Buzzer	No sound
Regulator	Closed

Table 3 explains several indicators of dangerous conditions in LPG gas cylinders, including when the LED light is red, the buzzer sounds, the regulator is open, and there is a notification from Blynk.

Table 3. Dangerous Conditions Gas Cylinder Leakage

Indicator	Conditions
LED	Red light
Buzzer	Sounded
Regulator	Opened
Blynk	Send Notification to Blynk

Based on the results of this study, the test results using the MQ-6 sensor on the distance and concentration of LPG gas showed that the distance between the LPG gas cylinder and the MQ-6 sensor had an effect. The closer the distance between the MQ-6 sensor and the gas cylinder, the higher the detected concentration of LPG gas. Conversely, the farther the distance between the MQ-6 sensor and the gas cylinder, the lower the detected value. This is illustrated in Figure 15.

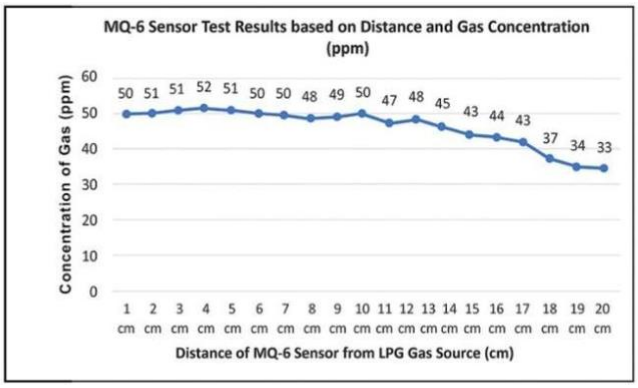

Figure 15. Testing of MQ-6 Sensors

Based on the results in Figure 16, the test results using the MQ-6 sensor show the effect of distance and time. The distance between the LPG gas cylinder and the MQ-6 sensor has an influence; the closer the MQ-6 sensor is to the gas cylinder, the faster the device can detect the LPG gas concentration. Conversely, the farther the distance between the MQ-6 sensor and the gas cylinder, the slower the device can detect the LPG gas concentration. However, if the distance between the device and the gas cylinder exceeds 16 cm, the device can no longer detect any gas leakage in the LPG gas cylinder.

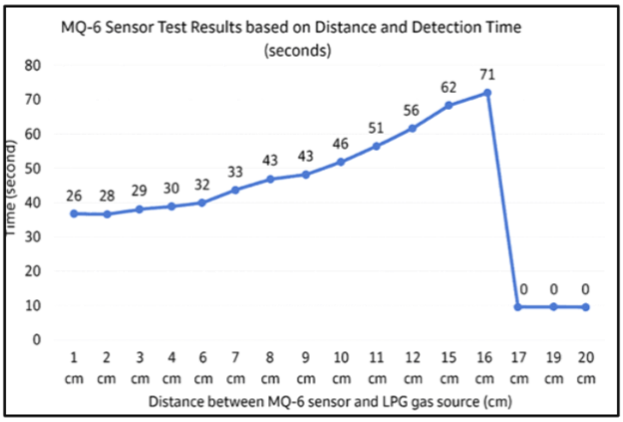

FIGURE 16. TIME-BASED TESTING OF MQ-6 SENSORS FOR DISTANCE

This research also conducted tests over a 3-day trial period, with the results shown in Tables 4, 5, and 6. Table 4 shows that when the LED light is green, the time required is 0 seconds, the buzzer does not sound, the detected gas level is 32 ppm, and the condition status is safe. When the LED light is yellow at 11 seconds, the buzzer does not sound, the detected gas concentration is 41 ppm, and the condition is deemed hazardous. However, if the LED light is red at 26 seconds, the buzzer sounds, and the gas concentration reaches 50 ppm, this also falls under the hazardous condition category.

TABLE 4. FIRST DAY OF EQUIPMENT TESTING RESULTS

Color of LED	Times (Second)	Buzzer	Concentration of Gas (ppm)	Conditions
Green	0	Off	32	Safe
Yellow	11	Off	41	Dangerous
Red	26	On	50	Dangerous

Table 5 explains that if the LED light is green, the time required is 0 seconds, the buzzer does not sound, the detected gas level is 34 ppm, and the condition status is safe. When the LED light is yellow at 9 seconds, the buzzer does not sound, the detected gas level is 40 ppm, and the condition status is considered dangerous. However, if the LED light is red at 26 seconds, the buzzer is sounding, and the gas level reaches 51 ppm, this is also considered a dangerous condition.

TABLE 5. SECOND DAY OF EQUIPMENT TESTING RESULTS

Color of LED	Times (Second)	Buzzer	Concentration of Gas (ppm)	Conditions
Green	0	Off	34	Safe
Yellow	9	Off	40	Dangerous
Red	26	On	51	Dangerous

Table 6 explains that if the LED light is green, the time required is 0 seconds, the buzzer does not sound, the detected gas level is 33 ppm, and the condition status is safe. When the LED light is yellow at 15 seconds, the buzzer does not sound, the detected gas level is 41 ppm, and the condition status is considered dangerous. However, if the LED light is red at 24 seconds, the buzzer sounds, and the gas concentration reaches 49 ppm, this also falls under the dangerous condition.

TABLE 6. THIRD DAY OF EQUIPMENT TESTING RESULTS

Color of LED	Times (Second)	Buzzer	Concentration of Gas (ppm)	Conditions
Green	0	Off	33	Safe
Yellow	15	Off	41	Dangerous
Red	24	On	49	Dangerous

The conclusion from the tests conducted for 3 days is that the device functions properly to detect leaks in LPG gas cylinders. Furthermore, the average gas concentration detected when the green LED light is on is 33 ppm, at the same time as 0 seconds. Furthermore, the average gas concentration detected when the yellow LED light is on is 40.6 ppm, with a required time range of 11.6 seconds. The average gas concentration detected for the red LED light is 50 ppm, with an average required time of 25.3 seconds.

5. CONCLUSION

The research results used the Internet of Things (IoT) system with MQ-6 sensors as leak detectors for LPG gas cylinders. Researchers tested the MQ-6 gas sensors indoors by detecting leaks in LPG gas cylinders from 1 cm to 16 cm. However, if the distance between the gas cylinder and the MQ-6 sensor exceeds 16 cm, the MQ-6 sensor cannot detect leaks in the LPG gas cylinder. The device will activate a red LED light (when the gas concentration is ≥ 45 ppm) and issue an alarm notification via a buzzer sound. Meanwhile, the LED light will turn green if the gas concentration is < 40 ppm. The LED light will turn yellow if the gas concentration is 41-44 ppm. The results of the three-day study showed that the average gas concentration detected when the LED light was green was 33 ppm, with the same time duration of 3 days, i.e., 0 seconds. Furthermore, the average gas concentration detected when the yellow LED light is on is 40.6 ppm, with a required time range of 11.6 seconds. Additionally, the average gas concentration detected for the red LED light is 50 ppm, with an average required time of 25.3 seconds. The research obtained from the tests conducted concludes that the LPG gas leak detection device functions properly. If a gas leak occurs, the device can activate an alarm through a buzzer and send gas concentration information to the user's smartphone via the Blynk app. A suggestion for further research is to notify users via WhatsApp that a gas leak has occurred.

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AUTHORS

Dian Novitaningrum
received her Bachelor of Informatics Engineering from Muhammadiyah Surakarta of University and then master of degree in Computer Science from Gadjah Mada University, Indonesia. She currently is a lecturer in Department of Informatics Engineering, Faculty of Computer and Design, Selamat Sri of University, Kendal, Indonesia. She has a research interest in Internet of Things (IoT), Machine Learning, Data Science and Medical Record.

Yuni Handayani
earned her Bachelor of Computer degree in 2018 and Master of Computer degree in 2021 from Dian Nuswantoro University (UDINUS). Currently, she is active as a lecturer at Selamat Sri University, with a research focus in Informatics Engineering, Data Mining, Internet of Things (IoT) and Artificial Intelligence. Her dedication is reflected through various academic and teaching activities that explore the application of classification algorithms, educational data mining techniques, and intelligent system development. Through her role as an educator and researcher, Yuni continues to contribute to strengthening the quality of education and innovation in the realm of information technology.

Taufik Hidayat
is a dedicated lecturer and researcher at the Informatics Engineering Study Program, Faculty of Computer and Design, Selamat Sri University, Indonesia. His academic work focuses on advancing knowledge in Data Mining, Information Systems, and Software Engineering, while also exploring applied areas such as Decision Support Systems, Data Analysis, and Web Programming. He has a growing interest in emerging

technologies, including the Internet of Things (IoT), Cryptography, and Cloud Computing. Through his research and teaching, he aims to contribute to innovation in computer science and support the development of practical solutions for real-world challenges.