

Air Leakage Detection for Metal Container

Ayan Pathan¹, Abhijeet Patil², Sandhya Prajapati³

Prof. Eva Gupta⁴

¹²³⁴Department of Electrical Engineering TSSM's Bhivarabai Sawant College of Engineering and Research, Narhe, Pune-41.

Abstract – This paper presents the design and development of an automated air leak detection system for metal tanks using the pressure decay method. The system is designed to detect small leaks in metal tanks used in industrial applications. It uses a pressure sensor, microcontroller, relay-controlled pneumatic system, and display unit to monitor pressure variation. The system improves accuracy, reduces manual inspection time, and ensures reliable quality testing. The proposed system is cost-effective, user-friendly, and suitable for industrial automation.

Key Words: *Leak Detection, Pressure Decay, Metal Tank Testing, Pneumatic System, Automation*

1. Introduction -

Leak detection in metal tanks is a crucial process in various industries such as automotive, chemical processing, and manufacturing. Metal tanks are widely used for storage and transportation of fluids, and even a small leakage can lead to safety hazards, environmental damage, and economic losses. Therefore, it is necessary to ensure that tanks are properly tested before being used in real-world applications.

With the advancement of technology, automation has become an important part of industrial systems. Automated systems help in improving accuracy, reducing human effort, and increasing productivity. Traditional leak detection methods such as water immersion testing and manual inspection are time-consuming and less efficient. These methods also depend heavily on human observation, which can lead to errors and inconsistent results.

In recent years, pressure-based leak detection techniques have gained importance due to their reliability and efficiency. Among these techniques, the pressure decay method is widely used because it is simple, cost-effective, and suitable for automation. In this method, air is filled inside the tank and the pressure is monitored over a period of time. Any drop in pressure indicates the presence of leakage. An embedded micro-web server, with IP connectivity for accessing and controlling devices and appliances remotely. The proposed system focuses on the development of an automated air leak detection system using a microcontroller, pressure sensor, relay module,

and pneumatic system. The system is designed to detect leakage accurately and provide quick results in the form of OK or NOT OK indication. This approach not only reduces testing time but also improves the overall efficiency of the inspection process.

2. AIM AND OBJECTIVE

The main aim of this project is to design and develop an automated air leak detection system for metal tanks using the pressure decay method. The system focuses on detecting leakage accurately and efficiently while reducing manual effort and inspection time. The proposed system improves reliability, consistency, and productivity in industrial applications.

- To design a system that can detect air leakage in metal tanks using pressure measurement.
- To implement the pressure decay method for accurate leak detection.
- To automate the testing process using a microcontroller-based system.
- To reduce human error and increase reliability in inspection.
- To provide clear indication of test results as OK or NOT OK.
- To improve testing speed and overall productivity.
- To develop a cost-effective and easy-to-use system for industrial applications.

3. LITERATURE SURVEY

[1] In this paper, the authors discuss the use of pressure-based leak detection methods for industrial applications. The pressure decay technique is widely used due to its simplicity, cost-effectiveness, and ability to detect small leaks accurately. The system measures pressure variation over time to identify leakage in sealed containers.

[2] This research focuses on the use of sensors and microcontroller-based systems for automation in leak detection. The integration of pressure sensors with embedded systems improves the accuracy and reliability of leak testing processes.

[3] The paper explains different non-destructive testing (NDT) techniques such as acoustic emission, tracer gas methods, and pressure testing. Among these, pressure-

based methods are preferred in industries due to their faster response and ease of implementation.

[4] Some studies highlight the importance of automation in industrial inspection systems. Automated leak detection systems reduce human effort, minimize errors, and increase productivity in manufacturing environments.

[5] Recent developments in leak detection systems include the use of digital sensors, real-time monitoring, and data analysis. These advancements help in improving system performance and provide better decision-making capabilities.

[6] Various research works also focus on improving the sensitivity of leak detection systems by optimizing parameters such as pressure range, stabilization time, and sensor accuracy.

Z.

4. BLOCK DIAGRAM

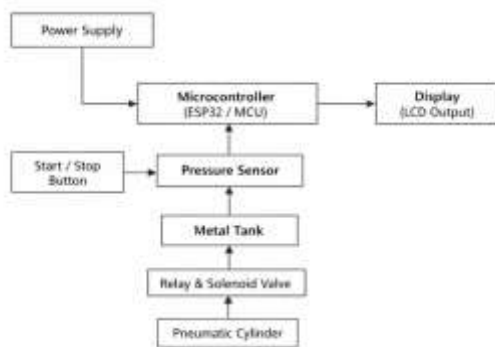


Fig. 1 Block Diagram of Air Leak Detection System.

Fig. 1 BLOCK DIAGRAM

The power supply provides the required voltage and current to all components in the system. A regulated DC supply is used to power the microcontroller, pressure sensor, relay module, and display unit.

The pressure sensor is used to measure the air pressure inside the metal tank. It continuously monitors the pressure variation during the testing process and sends the signal to the microcontroller.

The microcontroller acts as the main control unit of the system. It receives input from the pressure sensor and start/stop buttons. Based on the received data, it processes the pressure values and determines whether leakage is present or not.

The relay module acts as an interface between the microcontroller and the solenoid valve. It works as an electromechanical switch and controls the operation of the solenoid valve using low voltage signals.

The solenoid valve controls the flow of compressed air into the tank. It opens and closes based on the signal from the relay module.

The pneumatic cylinder is used to clamp and seal the metal tank properly before testing. It ensures that there is no external leakage during the process.

The display unit is used to show the pressure value and the final result of the test. It indicates whether the tank is OK or NOT OK.

The start/stop buttons are used to control the operation of the system manually.

The metal tank is the test object in which air is filled and pressure is monitored to detect leakage.

5. CIRCUIT DIAGRAM

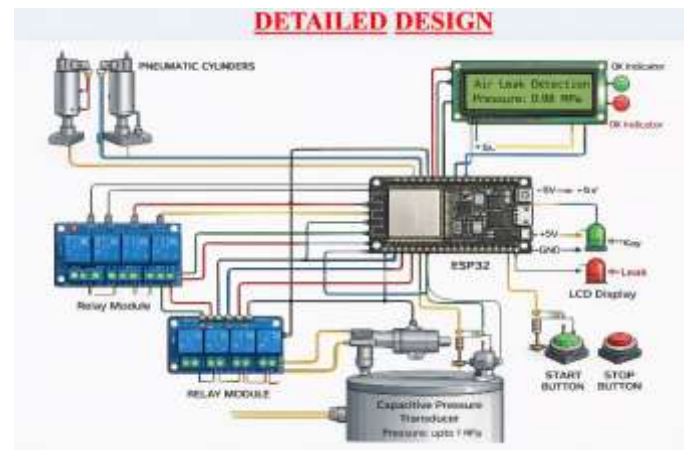


Fig. 2 CIRCUIT DIAGRAM

The circuit diagram represents the electrical connections of the Air Leak Detection System. A regulated 5V and 12V power supply is used to power the ESP32 microcontroller, relay module, pressure sensor, display unit, and other components.

The pressure sensor is connected to the analog input pin of the ESP32 and continuously measures the air pressure inside the metal tank. The microcontroller processes this data and determines the pressure drop to detect leakage.

The relay module is connected to the digital output pins of the ESP32 and is used to control the solenoid valve and pneumatic cylinder. When the relay is activated, it allows the flow of current to control the air flow mechanism.

The display unit (LCD) is connected using I2C communication and is used to display pressure values and test results (OK/NOT OK). The buzzer is connected to indicate leakage detection through sound alerts.

The start and stop buttons are connected to the input pins of the microcontroller to manually control the operation of the system.

The entire circuit works together to automate the air leak detection process efficiently and accurately. appliances when not using remote or wireless control. Relays act as electromechanical switches that control AC loads using small control signals from the ESP32. Each relay has: Input pin from ESP32 (for signal) Common (COM), Normally Open (NO), and Normally Closed (NC) terminals When ESP32 sends HIGH/LOW signal: The relay energizes or de-energizes. This switches the connected load (light/fan) ON or OFF. The AC loads such as: Bulbs (220V, 12W) – connected to first Six relays. Fan (220V, 35W) – connected to the Two relay. Each load is powered by AC supply (Live & Neutral) through the relay contacts. Bluetooth (HC-05): Used for wireless control via mobile app (short range). GSM (SIM800): Used for SMS-based or call-based control (long distance). Wi-Fi (ESP32 built-in): Used to connect with IoT dashboard or cloud for monitoring.

6. COMPONENTS



Fig. 3 ESP32 PIN DIAGRAM

The ESP32 microcontroller is used as the main control unit of the air leak detection system. It is responsible for processing the input signals from the pressure sensor and controlling the output devices such as the relay module, solenoid valve, pneumatic cylinder, and display unit. The ESP32 reads the pressure values from the sensor and compares them with predefined conditions to detect leakage in the metal tank.

The ESP32 controls the relay module to operate the solenoid valve and pneumatic cylinder during the testing process. It also sends data to the LCD display to show the

pressure readings and the final result as OK or NOT OK. The start and stop buttons are connected to the ESP32 to manually control the system operation.

The ESP32 is preferred due to its high processing speed, multiple input/output pins, and built-in features like Wi-Fi and Bluetooth, which can be used for future upgrades such as remote monitoring and data logging.

Fig. 4 RELAY

The relay module is used in the air leak detection system to control high voltage devices such as the solenoid valve and pneumatic components using low voltage signals from the ESP32 microcontroller. It acts as an electromechanical switch that allows the microcontroller to safely operate devices that require higher power.



When the ESP32 sends a signal, the relay gets activated and completes the circuit, allowing current to flow to the solenoid valve. This helps in controlling the flow of compressed air during the testing process. When the relay is OFF, the circuit is open and the device stops operating.

Fig.5 LCD



The LCD display is used in the air leak detection system to show the pressure readings and the final result of the testing process. It acts as a user interface between the system and the operator. The display provides real-time information such as pressure values and indicates whether the tested tank is OK or NOT OK.

The LCD is connected to the ESP32 microcontroller using I2C communication, which reduces the number of connection pins required. The microcontroller sends data to the LCD, and the display shows the corresponding output clearly. This helps the operator to monitor the system easily during operation.

The LCD display improves the usability of the system by providing clear and immediate feedback. It plays an important role in ensuring accurate and efficient leak detection.

Fig. 6 Capacitive Pressure Sensor

detection system to measure the air pressure inside the metal tank during The capacitive pressure sensor is used in the air leak the testing process. It is one of the most important components of the system, as it helps in detecting leakage by monitoring pressure variation.

The sensor works on the principle of capacitance change. When pressure is applied, a diaphragm inside the sensor moves, causing a change in capacitance. This change is converted into an electrical signal, which is sent to the

ESP32 microcontroller. The microcontroller reads this signal and calculates the pressure drop over time.



If the pressure decreases beyond a predefined limit, the system detects a leak and gives a NOT OK result. If the pressure remains stable, the tank is considered leak-free. The sensor provides accurate and reliable measurements, which improves the overall performance of the system.

7. METHODOLOGY

The methodology of the proposed air leak detection system involves a systematic approach for designing, developing, and testing the system. The process begins with identifying the problem of detecting small air leaks in metal tanks, which are difficult to detect using traditional manual methods.

A detailed literature study is carried out to understand existing leak detection techniques and their limitations. Based on this study, an automated system is designed using a microcontroller, pressure sensor, relay module, pneumatic components, and display unit.

The system design includes both hardware and software development. The hardware setup involves connecting the capacitive pressure sensor, relay module, solenoid valve, pneumatic cylinder, LCD display, and control buttons to the ESP32 microcontroller. The software is developed to read sensor data, process pressure values, and control the system operation based on predefined conditions.

After designing the system, fabrication and assembly of all components are carried out to build the complete setup. The microcontroller is programmed to monitor pressure changes and detect leakage using the pressure decay method.

Finally, the system is tested and calibrated under different conditions to ensure accuracy and reliability. The results are analyzed to evaluate the performance of the system in terms of leak detection capability, response time, and efficiency.

8. RESULT

The developed air leak detection system was tested under different operating conditions to evaluate its performance and accuracy. The system successfully detected leakage in metal tanks using the pressure decay method.

The experimental results show that the system is capable of identifying both leak-free (OK) and defective (NOT OK) tanks based on pressure variation over time. For leak-free tanks, the pressure remains stable after stabilization, whereas for defective tanks, a noticeable pressure drop is observed.

The total cycle time of the developed system is approximately 45 seconds per tank, which is significantly lower compared to traditional methods. This results in a higher productivity of around 60–80 tanks per hour. The system also reduces manual effort and improves consistency in testing.

In addition, the system shows improved energy efficiency by eliminating the need for high-power equipment such as ovens used in conventional methods. The cost analysis indicates a significant reduction in operational cost.

The results confirm that the proposed system provides reliable, accurate, and efficient leak detection, making it suitable for industrial applications.

9. CONCLUSION

In conclusion, the design and development of the air leak testing system for metal tanks represents a significant achievement in ensuring the integrity and safety of these critical components. This system, which was meticulously engineered and thoroughly tested, offers a reliable and efficient solution for detecting and preventing air leaks in metal tanks. Through this report, we have outlined the key aspects of the system's design, its development process, and the rigorous testing procedures that validate its performance. In summary, the design and development of the air leak testing system for metal tanks is a testament to the commitment to excellence in engineering and the pursuit of innovation in ensuring the quality and safety of critical infrastructure. This system is poised to make a substantial impact on the industry by enhancing the reliability and performance of metal tanks while minimizing the risks associated with air leaks. The results confirm that the proposed system provides reliable, accurate, and efficient leak detection, making it suitable for industrial applications.

9.References

1. AirLeakSlam: Automated Air Leak Detection Using Mobile Robots No author listed. (1990). In Proceedings of the 2019 IEEE International Conference on Robotics and Automation (ICRA), 2019, 6703–6709. Springer.
2. Leak Detection in Storage Tank Bottoms by Pneumatic Enhancement of Acoustic Emissions Lewis, U.S. (1991). United States Patent No. 5,052,215.
3. Sensor Cable-Based Tank Leak Detection System No author listed. (No date). United States Patent No. 5,890,279.
4. Tank Provided with Leakage Detector States Patent No. 5,508,799. Link
5. Liu, Y.-f., Shi, L.x., Sa, Q.-e., Zhang, T.-n., Chal, Y.-q., Si, X.-f., Wang, Y.-m., & Li, B. J. (2023). Exploration and Application of Acoustic Emission Detection Technology in Leakage Detection of the Bottom Plate of Crude Oil Metal Storage Tanks. *Journal of Hazardous Materials*, 435, 129080
6. Adsul, S., Sharma, A. K., & Mevekari, R. G. (2016). Development of Leakage Detection System. Proceedings of the 2016 IEEE International Conference on Automatic Control and Dynamic Optimization Techniques (ICACDOT), 673–677.
7. Rahimi, M., Alghassi, A., Ahsan, M., & Haider, J. (2020). Deep Learning Model for Industrial Leakage Detection Using Acoustic Emission Signal. *Informatics*, 7(4), 49.
8. Kumar, A., Sundarrajan, S., et al. (2007). Method and System for Leak Detection. United States Patent No. 7,267,032 B2. Link
9. Li, Z., Shui, A., Luo, K., Chen, J., & Li, M. (2011). SIR-Based Oil Tank Leak Detection Method. Proceedings of the 2011 IEEE International Conference on Industrial Technology (ICIT), 1–6.