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Leak Detection in Pipeline using Arduino

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Abstract— One of the main concerns of the Calatrava Water System are the leakage and location of water pipes. Therefore, we come up with this research to minimize leakage and to conserve more water. In this paper, we propose a Leak Detection of Pipelines using Arduino for us to detect the water leakage underground pipes are typically used to install water distribution systems. It is more difficult to monitor subterranean water pipes than surface-level water pipelines in open areas. If there is a disruption in the pipeline, such a leak, this will result in a permanent loss. Numerous things, including the age of the pipe, poor installation, and natural calamities, can result in leaks in pipes. Thus, in the event of a leak, a solution is needed to identify the damage and pinpoint its position.

Keywords— Arduino; DAWASCO; Leaks; Pipeline; Sensor

I. INTRODUCTION

A vital necessity for human survival is clean water. Water conservation is vital for environmental sustainability, economic efficiency, energy conservation, and ensuring the well-being of communities worldwide. It is a shared responsibility that requires individual and collective efforts to address the challenges of water scarcity and promote a more sustainable use of this precious resource. Addressing the problem of water losses due to pipeline disruptions requires proactive measures such as regular maintenance, monitoring systems, and investment in modern and resilient infrastructure. Implementing leak detection technologies and adopting sustainable water management practices can help mitigate the negative impacts of pipeline disruptions, ensuring a more reliable and efficient water supply system. To address water losses due to pipeline disruptions, it is essential to implement a proactive monitoring system in each area manually. This involves regularly checking the pipelines to identify and address any potential issues. Monitoring and inspecting the pipelines for problems such as leaks or damages are crucial steps in mitigating water losses. This proactive approach helps in maintaining the integrity of the water distribution system and ensures that any disruptions are promptly identified and rectified to prevent further losses. The Leak Detection in Pipelines using Arduino is used for monitoring the leakage. This will help to trace where the pipelines have a leakage and also to minimize the concerns about the higher water bill. In order to monitor the water leaks in the pipelines areas without checking manually, to take actions immediately when they detect leakage.

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Water Pipeline Monitoring and Leak Detection using Flow Liquid Meter Sensor, the Flow liquid meter sensor is one of the sensors that is used for the monitoring process. This sensor uses Hall Effect sensor inside it to measure the water flow rate and is placed on a pipe that has a diameter equal to the diameter of the sensor. The sensor will retrieve water flow data by analyzing rotation count of the wheel [1].

A microcontroller is required to process this data in order to know how the rate of water flow through. Then the data will be sent by the microcontroller to the end node via internet access. A water leakage detection system with SMS alert using the Node MCU, Water Flow Sensor, Ultrasonic Sensor, and Buzzer. In this project when the leak has occurred, the time taken by the system to deliver the SMS is reliant on the coverage area or range of the specified mobile network. In our project, we use the LCD screen to display the outputs immediately when the pipe leak [2]. A sensor-based leakage detection system that can notify the user of the water level through mobile application. Also, the system can measure the quality of water if it is less than or more than normal values then the notification is sent to the user as SMS. Leak detection takes place by using the water flow sensor which detects the flow of water. In this project, the hardware requirement is used as an ultrasonic sensor, mobile calling and SMS, water flow sensor, and pH sensor. In our project we use the LCD screen display to show the output of the readings in the sensors that have been installed in the pipeline to detect if there is a leak, also, to show the position or location of the leakage in a pipeline [3]. Water Leakage Detection System using Arduino is based on IoT with the water flow sensors integrated with Arduino to detect the leakage of water in pipelines and provide an alert on the leaks to the distribution authorities to prevent the loss of water flowing through the pipelines from the distribution centers to the consumers. So due to that, it helps most of the companies like Dar es Salaam Water Supply Company (DAWASCO) to know where there is a leak of the pipe at a certain geographical location where the flow meter sensors are installed and can be displayed on an LCD screen (Liquid Crystal Displays) [4]. In order to reduce the harmful effects of leaks and address their consequences as quickly as possible, new methods and strategies have to be used. Leaks need to be promptly found, fixed, and reported since they may sometimes have detrimental repercussions that lead to more significant issues. When leakage affects the community's essential source of fresh water, the issue gets considerably worse. Contaminants may seep into the water supply in addition to resource waste. The potential for environmental health catastrophes brought on by a delay in detecting water pipeline breaches has prompted study into the creation of techniques for pipeline leak and contamination detection nation-finding. Water network leaks have been a major issue globally, particularly in poorer nations where water is bare [5].

When implementing leak detection in pipelines using Arduino it does include the following:

1. Early Detection-Develop a system that can detect leaks at an early stage, allowing for prompt intervention and minimizing water losses.
2. Accuracy- Ensure that the leak detection system is accurate in identifying the location and severity of leaks to facilitate targeted repairs.
3. Cost-Effectiveness-Design a cost-effective solution that provides efficient leak detection without requiring extensive financial resources, making it accessible for a wide range of applications.
4. Real-time Monitoring-Enable real-time monitoring of the pipeline to promptly identifies and respond to any changes in water flow or pressure indicative of a potential leak.
5. Low Power Consumption-Design the system with low power consumption to ensure long-term operation without frequent battery replacements, especially in remote or hard-to-reach locations.
6. Integration with Existing Systems-Ensure compatibility and integration with existing pipeline infrastructure and monitoring systems, allowing for seamless adoption of the leak detection solution.
7. Remote Access and Control-Implement features that enable remote access and control, allowing operators to monitor the system and respond to leaks from a centralized location.
8. Data Logging and Analysis-Incorporate data logging capabilities to record historical information about water flow patterns and leak occurrences. Analyze this data to identify trends and improve the efficiency of the leak detection system.
9. Alerts and Notifications - Provide a mechanism for generating alerts or notifications when a potential leak is detected. This can include visual indicators, alarms, or automated notifications sent to relevant personnel.
10. Scalability-Design the leak detection system to be scalable, allowing for easy expansion to cover larger pipeline networks or additional monitoring points as needed.
11. User-Friendly Interface-Develop a user-friendly interface for configuring, monitoring, and managing the leak detection system. This may include a graphical user interface (GUI) or a web-based dashboard.
12. Weather Resistance - Ensure that the system components, including sensors and microcontrollers, are resistant to environmental factors such as moisture, temperature variations, and other conditions typically encountered in pipeline environments.

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13. Low Maintenance Requirements - Minimize the need for frequent maintenance by selecting durable and reliable components. Implement self-diagnostic features to alert operators when maintenance is necessary.
14. Compliance with Standards - Ensure that the leak detection system complies with relevant industry standards and regulations, providing a reliable and accepted solution for pipeline monitoring.

By addressing these objectives, a leak detection system using Arduino can contribute to efficient and effective monitoring of pipelines, reducing water losses, and promoting the sustainable management of water resources.

II. METHODOLOGY

Research Design
The study used descriptive developmental research for Leak Detection in Pipeline using the Arduino.

System Design
The researcher utilized Agile Development, which emphasizes flexibility and customer satisfaction through iterative and incremental development.

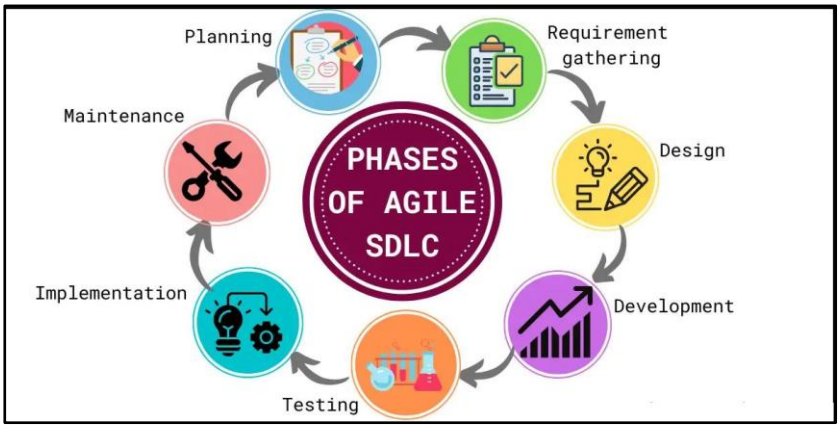

Fig. 1. **Agile Development SDLC**

Agile Development SDLC prioritizes rapid feedback, adapts to changing requirements, and values collaboration and communication among team members and stakeholders.

Planning: In the planning stage. The researchers aim to develop a pipeline leak detection system using Arduino to assist the residents of Calatrava. This involves identifying the need for a more efficient method of detecting pipeline leaks to prevent water wastage and mitigate potential damages.

Requirement Gatherings: During the requirement gathering phase, the researchers visit the Calatrava Water System field office to understand the current practices and challenges in leak detection through interviews with personnel and observations of their pipeline detection processes.

Design: Prototypes are built to test initial ideas, and feedback from potential users is collected to refine the design.

Development: The system is developed in parts, starting with the most important functions. The researchers and stakeholders regularly communicate to ensure alignment, and code is frequently reviewed to maintain quality.

Testing: In this stage, the system is tested using the PSSUQ regarding system usefulness, system information quality, and system interface quality to ensure it meets the end-users requirements.

Implementation: The system is ready for implementation after passing the testing stage. The developer assists the user in installing and using the system.

Maintenance: After installing the system, the developer provides maintenance and support. This also ensures that the system is updated as needed.

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Respondents of the Study

The respondents of the study are the personnel of the Calatrava Water System personnel and the residents of Calatrava, Negros Occidental.

Table 1.0 Summary of Respondents

Respondents	Sample Sizes
CWS Personnel	5
Residents	50
Total	**55**

Sampling Technique

The researcher used the convenience sampling technique since the system is intended to be developed and used by Calatrava Water System personnel and residents of Calatrava, Negros Occidental.

III.RESULTS

The system architecture for a leak detection system in a water pipeline using Arduino involves multiple components that work together to monitor, detect, and report leaks in real-time. The architecture includes sensors, Arduino microcontrollers, communication modules, and a central monitoring system. Below is a detailed breakdown of the components and their interactions.

Components

Sensors:

Pressure Sensors: Measure the pressure at various points in the pipeline. Flow Rate Sensors: Measure the flow rate of water in the pipeline. Temperature Sensors: Monitor the temperature of the water, providing additional context for pressure and flow rate data. Leak Detection Sensors (optional): Specialized sensors that directly detect the presence of water outside the pipeline (e.g., moisture sensors).

Arduino Microcontrollers:

Arduino Uno or Arduino Mega: Collect data from sensors and process it for leak detection.

Communication Modules:

Wireless Communication Modules (e.g., XBee, NRF24L01, or Wi-Fi modules like ESP8266): Transmit sensor data to a central monitoring system. Wired Communication (e.g., RS485): For stable and reliable data transmission over long distances.

Power Supply:

Battery Packs or Solar Panels: Ensure continuous operation of the Arduino and sensors.

Central Monitoring System:

Server or PC: Collects and processes data from all Arduino units. Data Storage: Database for logging sensor data and system events. User Interface: Dashboard for real-time monitoring, alerts, and historical data analysis.

Alerting System:

SMS Gateway: Sends text message alerts to maintenance personnel. Email Notifications: Sends email alerts when a leak is detected. Mobile App: Push notifications and remote monitoring. The leak detection data, summarized in Table 1, provides insight into the behavior of a pipeline over a series of six segments, monitored at five-minute intervals. The key metrics observed include pressure (psi), flow rate (gpm), temperature (°C), and whether leakage was detected. The results can be detailed as follows:

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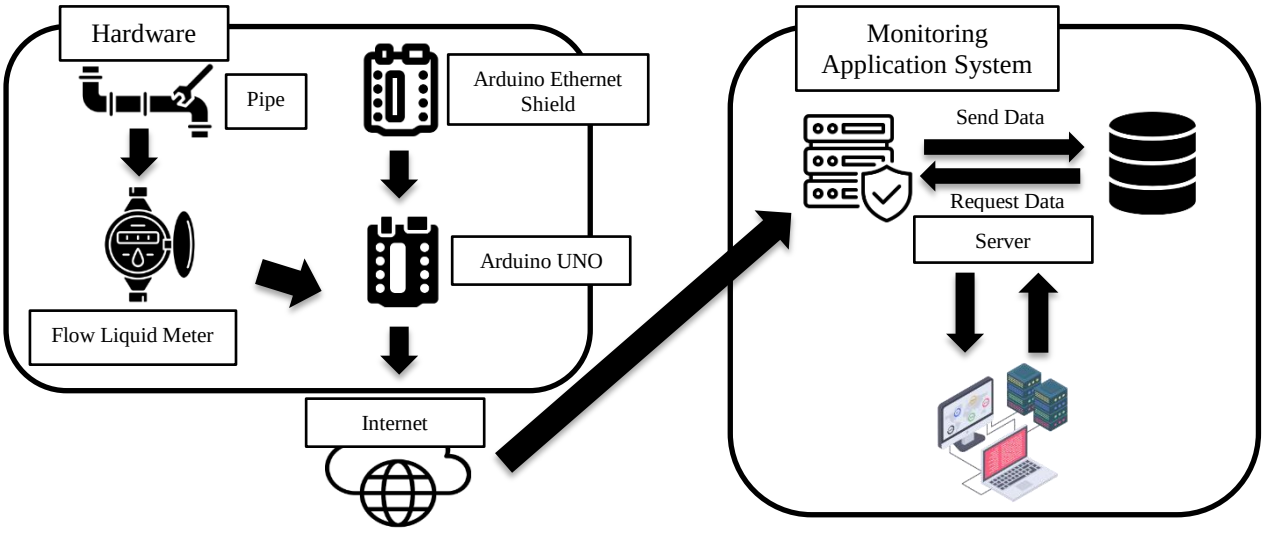

Fig. 2. **Architectural Design**

Pressure:
There is a consistent decrease in pressure over time across all segments. Starting at 50 psi in Segment 1, the pressure drops incrementally, reaching 25 psi by Segment 6.

Flow Rate:
Similarly, the flow rate decreases steadily from 100 gpm in Segment 1 to 75 gpm in Segment 6.

Temperature:
The temperature shows a gradual increase from 20°C in Segment 1 to 25°C in Segment 6.

Leakage Detection:
Leakage is detected starting from Segment 4 and continues through Segments 5 and 6. No leakage is observed in Segments 1, 2, and 3.

Table 1: Leak Detection Data

Pipeline Segment	Time (min)	Pressure (psi)	Flow Rate (gpm)	Temperature (°C)	Leakage Detected
Segment 1	0	50	100	20	No
Segment 2	5	45	95	21	No
Segment 3	10	40	90	22	No
Segment 4	15	35	85	23	Yes
Segment 5	20	30	80	24	Yes
Segment 6	25	25	75	25	Yes

IV. DISCUSSION

The data indicates a clear relationship between the decrease in pressure and the detection of leaks. From Segment 1 to Segment 3, pressure drops but no leakage is detected. However, from Segment 4 onwards, a further significant reduction in pressure corresponds with the presence of leakage. Specifically, the pressure drops from 35 psi in Segment 4 to 25 psi in Segment 6, during which leaks are detected in all segments. Similar to pressure, the flow rate decreases over time and shows a noticeable reduction when leaks are present. From 100 gpm in Segment 1, the flow rate decreases to 75 gpm in Segment 6. The significant reductions between

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Segments 3 and 4 (from 90 gpm to 85 gpm) and continuing through to Segment 6 correlate with the detected leaks. While temperature increases gradually over time, it does not appear to have a direct impact on leak detection based on the provided data. The rise in temperature from 20°C to 25°C does not show a clear pattern linked to the occurrence of leaks. The observed correlation between pressure/flow rate reductions and leak detections supports the hypothesis that these metrics can be effective indicators for identifying leaks. Implementing Arduino-based systems to monitor pressure and flow rate could potentially allow for real-time detection and timely intervention to address leaks in pipeline systems.

V. CONCLUSIONS AND RECOMMENDATIONS

The study demonstrates that monitoring pressure and flow rate is crucial in leak detection for pipelines. The data suggests that significant decreases in these metrics are strong indicators of leakage. While temperature monitoring provides useful context, it is less directly correlated with leakage events. Future work could involve the implementation of automated systems using Arduino technology to continuously monitor these parameters, improving the efficiency and responsiveness of leak detection and maintenance protocols in pipeline management. It is recommended to deploy Arduino-based systems equipped with pressure and flow rate sensors along the pipeline. These systems should continuously monitor the pipeline's pressure and flow rate to detect anomalies that may indicate a leak. Define threshold values for pressure and flow rate reductions that trigger an alert for potential leaks. For example, if pressure drops by more than 5 psi within a segment or the flow rate decreases by more than 10 gpm, an immediate inspection should be conducted.

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