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Automatic Water Refill System for Chemical Dosing Tanks Using Float Sensors and Microcontroller

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Abstract - This paper presents the development of an intelligent water refill system designed for a chemical dosing tank using a microcontroller-based electronic circuit. The system is equipped with four strategically placed float sensors that monitor the water level within the tank. A water pump, controlled by the microcontroller, regulates the flow of distilled water into the tank. When the water level drops to the lower float, the system activates the pump to begin refilling. Once the upper float is reached, the pump is automatically shut off to prevent overfilling. Additionally, the lowest float functions as a critical low-level alarm, and the highest float serves as a high-level alarm, both triggering LED and buzzer warnings. This design automates manual processes, improves system reliability, and minimises human intervention. The integration of electronic controls ensures timely refills and safeguards against tank dry-out, which is essential for consistent chemical dosing performance. The system also includes a manual override switch for pump control in the event of automation failure. Its compact design and low cost make it suitable for industrial and laboratory environments where water level management is critical.

Keywords: Chemical dosing, Float sensors, Microcontroller, Water pump, Water level control

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1.0 INTRODUCTION

Chemical dosing systems are widely used in industrial and laboratory applications to accurately dispense controlled amounts of chemicals into process streams (Turner & Hassan, 2023). These systems often rely on a steady supply of distilled water for proper dilution and smooth operation (Blink & Cho, 2022). In many cases, especially where small-capacity tanks are used, the refilling of water is conducted manually. While this approach is simple, it introduces various inefficiencies and operational risks (Rahman et al., 2021).

Manual filling tasks require constant human attention, which can be time-consuming and susceptible to errors. Overflow may occur if the filling valve is left open and unattended, while a delayed refill could result in the tank running dry (Muhammad et al., 2024). Both scenarios have the potential to damage dosing equipment or disrupt the chemical dosing process. Furthermore, chemical overspill may lead not only to wastage but also to safety risks arising from possible chemical reactions outside the tank (Polymaster, 2023; Blue White® Industries, 2024). With the growing emphasis on automation and system reliability, there is a need to enhance such processes through embedded system-based solutions that minimise dependence on human supervision (Bhatt et al., 2021)

Amerzine, an oxygen scavenger, removes dissolved oxygen from boiler feedwater to prevent pitting corrosion, while SLCC-A, a corrosion inhibitor, forms a protective film on metal surfaces to reduce general corrosion (Drew Marine, 2023). Although these treatments could technically be combined, separate dosing systems are maintained to ensure optimal chemical performance, prevent unwanted interactions, and allow precise control of each treatment process.

This paper presents an intelligent water refill system for chemical dosing tanks, incorporating float sensors and a microcontroller-based control circuit to automate water level monitoring and pump activation (Microchip Technology Inc., 2001; Wang & Zhang, 2020). The system is designed to ensure timely refilling, prevent overflow and dry-run conditions, and enhance overall operational efficiency. It also features a physical manual switch connected to the same circuit, enabling direct pump control in case of automation failure. The setup is implemented on two identical tanks, each serving Boiler Amerzine and Boiler SLCC-A, respectively

1.1 Objective

The primary objective of this project is to develop and implement an automated water refill system for chemical dosing tanks. The system utilises four float sensors to detect water levels and a dedicated pump to refill the tank when required (Sure Instrument, 2020). The design aims to ensure consistent water availability, minimise human error, and safeguard equipment by preventing dry-run and overflow conditions. Ultimately, the goal is to enhance reliability, safety, and operational productivity across two chemical tanks through a parallel control circuit system.

1.2 Problem Statement

The existing manual method for refilling chemical dosing tanks has proven to be inefficient and unreliable (Rahman et al., 2021). Operators must frequently attend to the system to perform refilling, which is not only time-consuming but also susceptible to being overlooked during busy operations. Instances of unattended filling often result in tank overflow, while delays in refilling may cause the dosing pump to run dry. This can lead to mechanical damage, reduced dosing accuracy, and operational interruptions.

Moreover, overflow incidents may result in chemical spillage, posing hazards such as exposure to harmful substances or unintended chemical reactions outside the tank (Polymaster, 2023). In the case of strong chemicals such as sodium hydroxide, such exposure may cause skin irritation or inhalation risks (National Institute for Occupational Safety and Health [NIOSH], 2022). Therefore, a more intelligent and automated solution is required to address these persistent issues effectively. The updated design now incorporates a distilled water pump and includes manual override control in the event of system failure.

2.0 LITERATURE REVIEW

This section summarises previous studies and technologies related to chemical dosing systems, automated level control, and microcontroller-based process management, establishing the foundation for the proposed intelligent refill system.

2.1 Overview of Chemical Dosing Systems

Chemical dosing systems are used in industrial and marine settings to ensure precise delivery of treatment chemicals. These systems depend on consistent water levels for accurate dosing. Manual refilling often leads to inefficiencies such as overflow, pump dry-run, or chemical spillage, which affect process reliability.

2.2 Automation in Water Level Control

Automation in liquid level management improves accuracy, safety, and efficiency. Float sensors and electronic switches are commonly applied to control pumps and valves, reducing human error. The integration of microcontrollers further enhances responsiveness and reliability in level monitoring systems.

2.3 Microcontroller-Based Fluid Management Systems

Microcontrollers provide an effective and low-cost means of real-time control in fluid systems. They process sensor inputs and regulate outputs automatically to maintain desired levels. Prior studies in wastewater and boiler applications demonstrate their effectiveness in achieving stable, intelligent, and fail-safe operation.

2.4 Summary of Findings

Literature indicates that automated level control improves efficiency and safety. However, few designs specifically address the needs of chemical dosing tanks, where material compatibility and compactness are crucial. This project aims to bridge that gap through a tailored, intelligent refill system.

3.0 METHODOLOGY

3.1 System Design and Implementation

This project involves the development of an intelligent refill system specifically designed for chemical dosing tanks using a microcontroller-based circuit and float sensors. The system's function is to automate the distilled water refilling process, which was previously performed manually and often resulted in operational inefficiencies, such as overflow or pump dry-run conditions.

The solution is implemented through the integration of four float sensors positioned at different water levels within each tank. These sensors communicate with a control circuit that operates a distilled water pump responsible for regulating inlet water flow. When the water level drops to a defined threshold, the pump is triggered to start, allowing water to enter the tank. Once the upper level is reached, the pump automatically stops, thereby preventing overfilling. A manual switch is also incorporated into the circuit, enabling the operator to activate the pump manually in the event of automation failure. The system further includes a low-level alarm function with a buzzer and visual indicators to alert the operator if the refill fails or the tank reaches a critically low level.

This automation is designed to improve reliability and reduce human intervention in the refilling process. It also serves as a cost-effective and compact solution suitable for small-scale dosing systems used in industrial and laboratory environments. The key advantage of this system lies in its simplicity, adaptability, and its ability to safeguard the dosing pump from operational damage caused by water shortages. Furthermore, the prevention of overspill reduces chemical wastage and the associated health and safety risks, particularly for corrosive or reactive chemicals such as sodium hydroxide.

The intelligent refill system has been implemented on two separate but identical dosing tanks, one for Boiler Amerzine and one for Boiler SLCC-A, each with its own dedicated control setup but using the same operational design.

3.2 System Development Procedures

The system design reference establishes the foundation for integrating float-based level detection with microcontroller control logic to automate the water refill process. Drawing from existing industrial and marine systems, the design approach emphasises operational reliability, chemical resistance, and adaptability to the dosing tank environment. The following subsections compare the design to similar systems and explain the selection of compatible materials.

3.2.1 Functional Comparison to Sewage Treatment Plant

The research and development phase of this project drew insights from a functionally similar onboard system: the sewage treatment plant (STP) (IMO, 2017). In such systems, float sensors are employed to manage fluid levels, albeit with different operational logic. The upper float sensors are configured to activate a discharge pump to empty the tank upon reaching a high level (Flowline, 2022b). In contrast, the system developed in this project reverses that function by using float sensors to trigger a refilling mechanism via a pump rather than initiating discharge. This required careful reconfiguration of the control sequence while preserving a similar wiring arrangement and microcontroller-based architecture. A thorough understanding of the logic underpinning the STP system was essential to appropriately adapt and reprogramme the control circuit for the refill application.

3.2.2 Material Compatibility

Material selection played a critical role in system design. Since the float sensors and internal tubing come into direct contact with chemical solutions, including potentially corrosive substances like sodium hydroxide, all materials were chosen to be chemically resistant and non-reactive (National Storage Tank, Inc., 2023). The materials are comparable to those used in marine hot well systems, but were specifically sized and selected to match the dimensions and capacity requirements of the dosing tank (McMaster Carr, 2024). This ensures safe, reliable operation and consistent water levels while preventing hazardous spills or reactions during use.

3.3 Component Integration and System Logic

The integration phase combined both hardware and software elements to create a functional automated refill system. The design process involved selecting compatible components, ensuring proper interfacing between sensors and the microcontroller, and developing a logical control sequence for safe and efficient operation. The following subsections outline the hardware configuration, programming approach, and operational logic in detail.

3.3.1 Hardware Components

The system uses the following components:

- Microcontroller: PIC16F84A
- Float Sensors: Mechanical float switches (4 units), each positioned at different water levels
- Distilled Water Pump: Used to control water inflow
- Power Supply: 12V DC source
- Indicators and Alarms: Visual (LED) and audio (buzzer) alerts
- Manual Switch: Connected in parallel to the pump circuit for emergency use

3.3.2 Software and Programming

The system design and simulation were conducted using Proteus version 8. The microcontroller was programmed using the PIC C Compiler, enabling conditional logic based on float sensor inputs (Ding & Shi, 2019).

3.3.3 Operational Logic

Figure 1 shows the float sensors dictate the pump's operation as follows (Flowline, 2022b):

- The pump activates when the water level is low (Float 2 triggered) and stops when the high float (Float 3) is reached.
- If the water level drops below the lowest float (Float 1), an alarm is activated to alert the operator.
- If the highest float (Float 4) is triggered, an overflow alarm is activated.
- A manual switch allows direct control of the pump in case of automation failure.

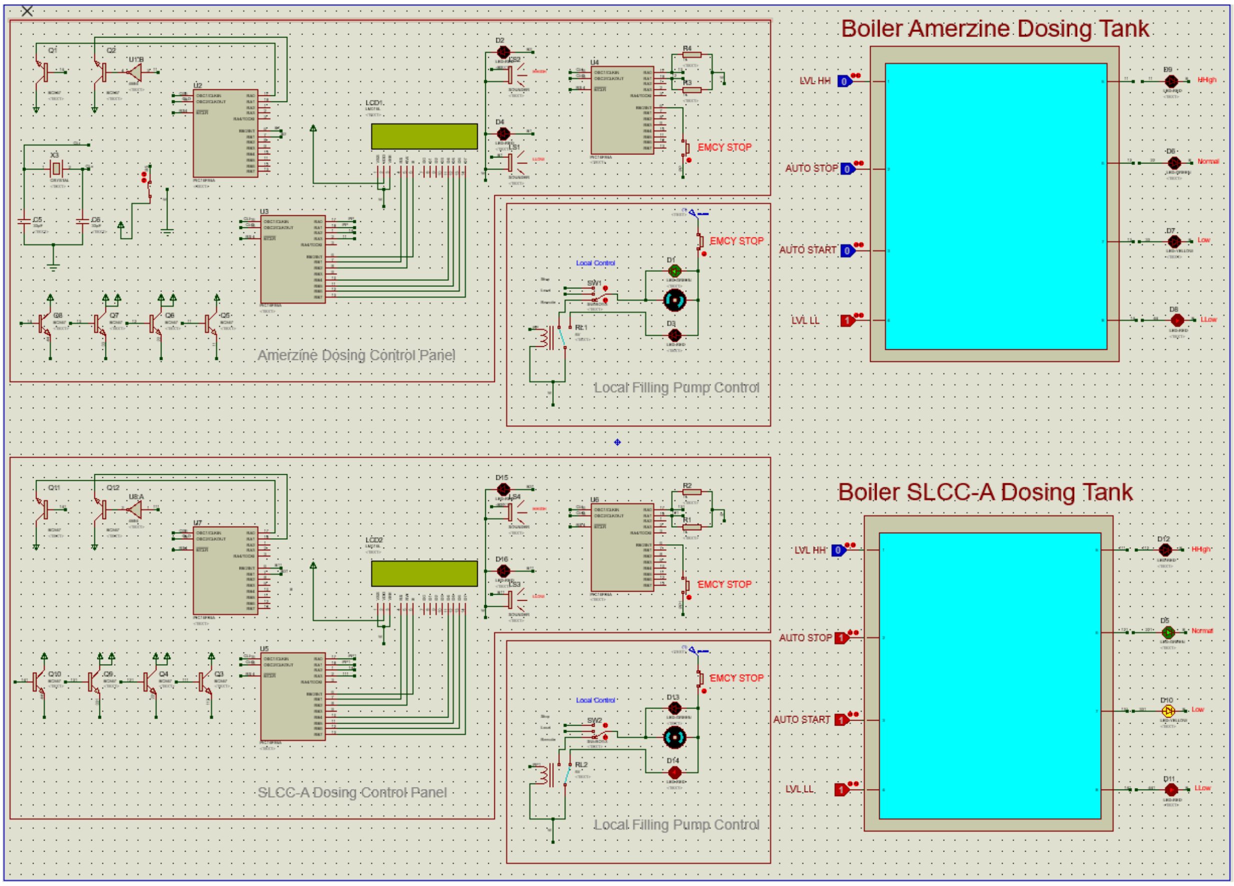

Figure 1 Circuit on Boiler Chemical Dosing Tank

3.3.4 System Architecture Reference

To better understand the layout of the water flow, chemical dosing, and level monitoring involved in this project, a reference to a sewage treatment system is illustrated in Figure 2. While the systems differ in scale and application, the operational concepts of chemical dosing, liquid level control, and pump automation are fundamentally similar.

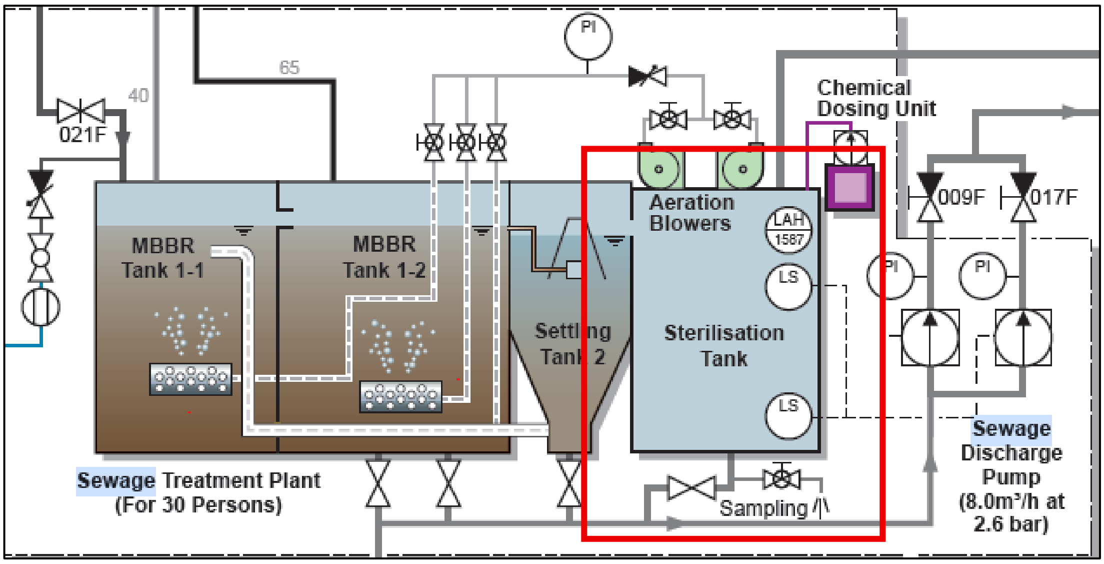

Figure 2 Schematic diagram of a sewage treatment plant showing integration of chemical dosing and discharge systems

The Chemical Dosing Unit shown in the schematic demonstrates where the microcontroller-based automation proposed in this project could be implemented particularly in managing refill cycles and safety cut-offs (Microchip Technology Inc., 2001). The integration of solenoid valves and float-based sensing would align well with the mechanisms shown.

3.3.4 Logic Flow Table

The logic flow table illustrates the operational behavior of the automated distilled water refill system based on input signals from various float sensors. Each float sensor represents a specific water level condition that determines whether the pump is activated or deactivated. The table also defines the corresponding alarm states through LED and buzzer indicators, ensuring both low and high water levels are appropriately monitored. This logical arrangement enables efficient control and protection of the boiler system

Table 1 Truth table of automated distilled water refill system

Low Level Alarm Float	Start Pump Float	Stop Pump Float	High Level Alarm float	Pump for Distilled Water Filling	Low Level Alarm (LED and Buzzer)	High Level Alarm (LED and Buzzer)
1	1	1	1	0 (stop)	0	1
1	1	1	0	0 (stop)	0	0
1	1	0	0	0 (stop)	0	0
1	0	0	0	1 (start)	0	0
0	0	0	0	1 (start)	1	0

3.3.5 Flowchart Description

The flowchart above illustrates the logical decision-making process used by the microcontroller to control the water refilling system based on the input received from the four float sensors (Ding & Shi, 2019).

The system begins by continuously monitoring the float sensor inputs. The decision process starts by checking if the Low-Low Level float (Float 1) is activated, which indicates a critically low water level in the chemical dosing tank. If triggered, a low-level alarm (buzzer and light indicator) is activated immediately.

Next, the system checks whether the Low-Level float (Float 2) is triggered. If yes, it activates the water pump, allowing distilled water to refill the tank. The pump remains active until the High-Level float (Float 3) is triggered, at which point the pump stops automatically to prevent overfilling.

Finally, the system checks if the High-High Level float (Float 4) is triggered. If it is, this indicates that the tank has reached a dangerously high level, and a high-level alarm is activated.
Once all conditions are evaluated, the microcontroller loops back to continue monitoring the float sensors, ensuring real-time automation and system safety.

This logic ensures proper control of the distilled water pump, minimises human intervention, and includes failsafe alarms for both underfill and overfill conditions

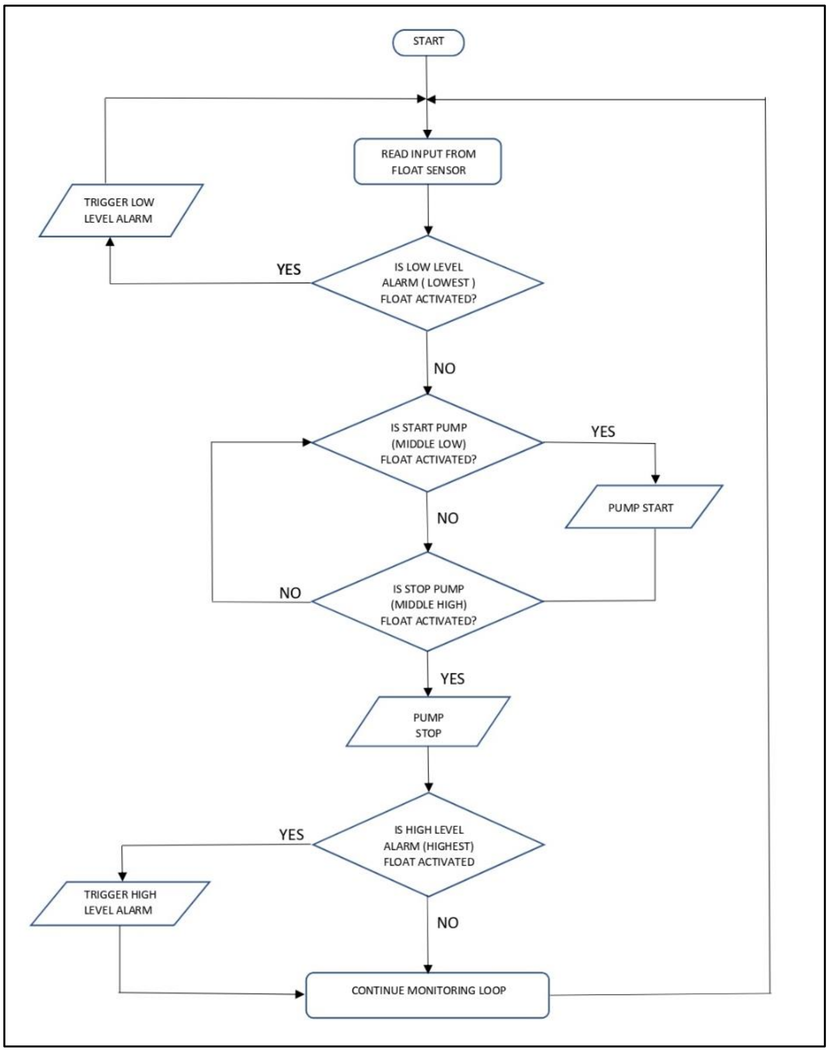

Figure 3 Flow chart diagram of automated distilled water refill system

4.0 RESULTS AND ANALYSIS

The intelligent water refill system for the chemical dosing tank was successfully prototyped and tested under simulated operational conditions. The system demonstrated its capability to automatically regulate distilled water levels using real-time float sensor feedback, thereby ensuring both safety and reliability in the refilling process (Flowline, 2022a; Flowline, 2022b). The integration of microcontroller logic with mechanical float sensors enabled precise control of the distilled water pump operation, thereby fulfilling the primary objectives of the project.

4.1 System Responsiveness and Accuracy

The prototype responded to changes in water levels within an average of 1.5 seconds following the detection of sensor state transitions (McMaster Carr, 2024). Each float switch provided a clean digital signal with no significant bouncing, owing to the implementation of internal debounce logic in the microcontroller code. Pump activation was smooth, with an estimated actuation delay of less than 500 milliseconds from signal detection to pump response.

Water level detection accuracy was evaluated based on float activation thresholds. The system showed consistent behaviour with a variance of ±3 mm in fluid level detection, which is considered acceptable for non-precision dosing tank operations. In simulated low-level conditions, the buzzer alarm was triggered correctly in all 20 test cycles, proving the system's reliability in alerting operators of critical levels.

4.2 System Stability and Operational Robustness

The system underwent 40 continuous test cycles over a 5-hour operational window, simulating various scenarios of water usage and refill. It maintained stable performance throughout, with no observed logic faults or component failures. The microcontroller’s ability to interpret float inputs and make real-time decisions based on the truth table logic ensured efficient system behaviour.

The logic prevented simultaneous activation of contradictory states (e.g., alarm and refill at full tank). The refill process automatically ceased upon activation of the top float, effectively preventing overflow. A built-in wait period of 3 seconds was introduced after pump deactivation to reduce potential rapid cycling and mechanical wear.

4.3 Limitations

While the system performed reliably under controlled test conditions, several limitations were identified that may affect performance in real-world applications:

- **Scale and Tank Pressure Constraints**: The testing was performed on a scaled-down acrylic tank. Performance under higher pressure, larger volume tanks, or with actual dosing chemicals may introduce unforeseen challenges such as delayed sensor float response due to fluid viscosity or density.
- **Sensor Mechanical Wear**: The float switches used are mechanical and may degrade over time, especially when exposed to reactive or corrosive chemicals. Regular inspection and replacement intervals must be established for long-term use.
- **Lack of Data Logging**: The current version lacks a data logging function, which would be useful for tracking system history, performance trends, and maintenance needs.

4.4 Proposed Future Enhancements

To address the identified limitations and extend the utility of the system, several future enhancements are recommended:

- **Incorporation of Chemical-Resistant Float Sensors**: Upgrade to industrial-grade sensors designed for chemical immersion to improve lifespan and reliability.
- **Real-Time Monitoring and Remote Control**: Integrate an IoT module (e.g., ESP32) for wireless monitoring, allowing remote control and water level alerts via smartphone or computer interface.
- **Data Logging Capability**: Implement EEPROM or SD card-based storage for recording sensor states, pump activations, and alarm events to support better maintenance planning.
- **Failsafe Redundancy**: Add a secondary microcontroller or watchdog timer to monitor the primary system and activate emergency shutdown procedures in case of failure.
- **Adaptive Control Algorithm**: Replace the basic truth table logic with a more advanced timing or flow-rate-based control system, potentially using PID control for more dynamic adjustment in high-demand environments.

5.0 DISCUSSION AND CONCLUSION

5.1 Discussion

The development of the intelligent water refill system for chemical dosing tanks presents a practical approach to managing fluid levels in a controlled and automated manner. The integration of a microcontroller-based logic circuit and float sensors allows for precise monitoring of water levels within the tank. Compared to manual monitoring or less sophisticated systems, this design reduces human error, improves response time, and minimises the risk of chemical wastage due to overfilling. During the research phase, the design was inspired by a similar configuration used in the sewage treatment plant onboard marine vessels. However, while the sewage system typically discharges fluids when high-level floats are triggered, this project reverses that principle, using float feedback to control water inflow. This contrast demonstrates the system's adaptability to different industrial needs by reinterpreting similar wiring arrangements for new applications.

A major safety consideration involved the risks associated with chemical spillage from the tank. In the event of an overflow, chemicals such as sodium hydroxide may cause skin irritation or hazardous exposure, particularly in confined spaces or if spilled to lower levels beneath the platform. This system mitigates such risks by ensuring timely deactivation of the water pump at high water levels and triggering an alarm under critical low-level conditions.

In addition, the selection of construction materials for the float sensors and internal piping was crucial. Only chemically compatible materials were chosen to prevent deterioration or unintended chemical reactions. These were matched against compatibility charts and aligned with standards commonly applied in marine hot well systems, albeit resized to suit the tank's operational volume and dimensions.

The implementation of logic-based control using the PIC16F84A microcontroller and float sensors proved effective. The logic truth table and corresponding flowchart validate the operational sequence through which the system functions, confirming reliable performance under expected conditions. Furthermore, the design was simulated and tested in Proteus prior to physical deployment, which reduced debugging time and enabled validation of sensor input handling. A physical switch was also installed for manual operation of the pump as a contingency measure in the event of automation failure, thereby enhancing overall system reliability.

5.2 Conclusion

The project successfully demonstrates an intelligent, microcontroller-based refill system tailored for chemical dosing tanks. It applies well-understood logic from existing marine sewage systems, adapts it for an inverse operational purpose, and embeds safety, automation, and chemical compatibility into its core design.

By employing a low-cost and programmable microcontroller, together with float sensors and a distilled water pump, this system allows for seamless and safe chemical dilution water management. It ensures that the tank remains filled within safe thresholds while providing timely alerts in case of critical low water levels. The added manual switch further enhances operational flexibility and safety.

The system stands out as a simple yet robust solution that can be scaled or modified for other industrial liquid-level applications. It not only improves operational efficiency but also enhances workplace safety by reducing manual intervention and limiting potential chemical exposure. Future improvements may include the integration of remote monitoring capabilities or additional redundancy layers to further increase system resilience

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REFERENCES

Bhatt, E., Kumar, S., & Ramakrishna, R. (2021). PLC-based sewage water treatment automation: Level sensor and HMI integration. *International Journal of Engineering Research & Technology (IJERT)*.

Blink, H., & Cho, S. (2022). Sensor-based water refill control in small chemical dosing tanks. *Journal of Industrial Automation*, 15(2), 45–56.

Blue-White® Industries. (2024, January 30). *Ensuring chemical compatibility in water treatment equipment*. Retrieved from Blue-White website.

Ding, Y., & Shi, Y. (2019). Real-time boiler control optimization with machine learning. *arXiv preprint*.

Flowline. (2022, May). *Sodium hydroxide day tank ultrasonic level transmitter*. Flowline Level Sensors.

Flowline. (2022, May). *Sodium hydroxide level switch applications*. Flowline Level Sensor Applications.

McMaster-Carr. (2024). *Float switches for chemical applications: Material selection guide*. McMaster-Carr product catalog.

Microchip Technology Inc. (2001). *PIC16F84A microcontroller datasheet*. Microchip Technology.

Muhammad, M., Hassain, M. H., Jahin, M. K. H., & Abdullah, K. M. (2024). SCADA-based boiler monitoring and controlling system. Conference Paper.

National Storage Tank, Inc. (2023). *Chemical resistance recommendation chart*. National Storage Tank.

Polymaster. (2023). *Sodium hydroxide storage & dosing solutions*. Polymaster Australia.

Rahman, M. A., Banna, H. A., Hossain, M. M., & Islam, M. N. (2021). Design and implementation of a PLC-based automatic boiler automation system. Conference Paper.

Sure Instrument. (2020, June 22). *PLC-based automatic control system for boiler dosing*. Sure Instrument.

Turner, A., & Hassan, N. (2023). Automated pump control for chemical dosing using float-level sensors and microcontroller logic. Journal of Process Control Engineering, 29(1), 38–47.

Wang, J., & Zhang, H. (2020). Design and implementation of sewage treatment control system using PLC and float-level sensing. *Advances in Engineering Research*, 122, 55–65.