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Pressure Decay Test Bench for Water Filter Testing by Using LabVIEW

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Abstract: We need to make sure that water filters are safe and work properly. This is important for keeping our water clean and people healthy. If there are leaks or problems with the filters that we do not find they will not work well as they should and people could get sick.This project is, about making a machine to test water filters. The machine is called an automated Pressure Decay Test Bench. It uses a computer system to control everything. It is connected to a program called LabVIEW.The machine tests the water filter by filling it with air and then checking to see how fast the air leaks out over a certain amount of time. This helps us know if the water filter is working correctly. We use the water filter to make sure our water is clean and the machine helps us know if the filter is doing its job. The water filter is an important thing and the machine is helping us to keep it safe. When the pressure drops much we know there is a leak. This way we can find the smallest problems. We use an ABB PM556 PLC to automate things, which means people do not make mistakes. This also means we get the results every time and we can test things faster than if we did it by hand. We use LabVIEW to watch what is happening in time to get the data to see what it means and to store the results of the tests. The system has parts, like pressure transmitters, solenoid valves, manifolds and a compressor. These parts help us control the pressure precisely and measure it accurately. We use the ABB PM556 PLC and LabVIEW to make sure the pressure control and measurement system works correctly. Experimental results demonstrate that the developed test bench provides reliable, efficient, and repeatable leak detection, making it suitable for industrial quality control applications in water filter manufacturing**.**

Keywords*:* Pressure Decay Test, Water Filter Testing, Leak Detection, PLC Automation, LabVIEW, Quality Control, Pressure Monitoring.

I. INTRODUCTION

Water is really important for people to be healthy and happy. That is why we need to have water filtration systems at home in factories and in offices. Because a lot of people want water it is crucial that these systems work properly and do not leak.Even tiny leaks, in a water filter can make it work not well as it should and let bad things get into the water. This means the water will not be as clean as we want it to be. Water filtration systems and water filters are very important to keep our water clean. Leak detection methods like soap bubble tests and visual inspection can take a time. They are not very reliable. It is hard to find small leaks with them. This is a problem because these methods are not good enough for factories where many filters need to be checked every day. The factories need to test thousands of filters and these traditional leak detection methods are just not suitable for that. Leak detection methods such, as bubble point tests and diffusion tests have the issues.To deal with these problems we need to use automated and precise testing techniques. The Pressure Decay Test method is a way to find even small leaks. It works by watching the pressure changes in a sealed water filter over time. This project is, about designing and building an automated Pressure Decay Test Bench to test water filters. We are using an ABB PM556 Programmable Logic Controller and LabVIEW to make this happen. The Pressure Decay Test Bench is what we are focusing on. We want to use the Pressure Decay Test method to make sure water filters are working properly. The system integrates pressure sensors, solenoid valves, manifolds, and an air compressor to ensure accurate pressure control, real-time monitoring, and repeatable results. By automating the testing process, the proposed system enhances testing speed, reduces human error, and improves overall quality control, making it well-suited for industrial water filter manufacturing applications.

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1.1 Motivation of Work

People really need safe drinking water. This means we are using water filtration systems more and more in our homes in factories and in offices. Water filters are the thing that stops bad stuff from getting into our water. So it is very important that they are strong and do not leak. Even small problems when they are made or tiny leaks can make them work badly and make the water not good to drink. This can be bad for peoples health. Because of this we really need ways to test water filters when they are being made and checked for quality. We need to make sure water filters are good so we can have water. Water filtration systems are very important, for safe drinking water.People usually use methods like soap bubble tests and visual inspection to find leaks. They also use bubble point tests and diffusion tests.. These methods have a lot of problems. They take a time to do and the person doing the test has to be very good at it. These methods are not good at finding small leaks. The thing is, these methods do not always give the results. They are not good, for places where a lot of things are being made and tests need to be done. Companies that make a lot of things need systems that can test things automatically. Leak detection systems need to be able to give repeatable results without being biased. This is because the scale of production is getting bigger and bigger. Companies need automated leak detection systems that can deliver repeatable results.The pressure decay method is really good at finding leaks. It does this by watching how the pressure changes over time. I like this method because it is simple and it works well. So we want to make a machine that can do the pressure decay test by itself. We are going to use a computer system to control the machine and a program called LabVIEW to watch what is happening and collect data. This way we can see what is going on in time and make decisions without having to do it ourselves. The pressure decay test bench is going to make testing water filters easier and faster. It will also help us make sure that the quality of the filters is always good. We will not have to get involved much which is a good thing. The machine will do the work for us. It will do it quickly. The pressure decay test bench will help us with quality control. That is important, for water filters. The motivation behind this work is to bridge the gap between traditional manual testing methods and modern industrial automation requirements, thereby enhancing the reliability, efficiency, and safety of water filter manufacturing processes.

1.2 Objectives of Work

1. To design and develop a pressure decay test bench for water filter testing.
2. To Automate the testing process using a PLC.
3. To Accurately detect leaks in water filters by monitoring pressure drop.

II. LITERATURE REVIEW

1. Pressure Decay Leak Testing for Filtration Products (Hoffmann, 2018)

Hoffmann did a thorough study on using pressure decay methods to test for leaks in industrial filtration systems. He found out that this method is really good at finding leaks that you cannot see with your eyes or with bubble tests. To get results you need to make sure the pressure is stable everything is sealed properly and the pressure sensors are accurate. This study helps us choose the pressure decay method, for our project because it is very sensitive and does not hurt the water filters.

2. Automated Pressure Decay Test Bench for Industrial Filters (Rajesh et al., 2020)

Rajesh and his colleagues found out that using a machine like this really helps to reduce errors and get the results every time. This is similar to what we're doing in our project, where we use a special kind of computer called a PLC to test water filters in a consistent and efficient way. The water filter testing is done using this automation, which's similar to what Rajesh and his colleagues did with their automated pressure decay test bench, for industrial filter testing applications.

3. Pressure Decay Method for Quality Assurance in Manufacturing (Chang et al., 2019)

Chang and the other people who worked with him looked into using pressure decay techniques to make sure things are good in places where things are made. They found out that pressure decay testing is really good for making a lot of things because it's simple and fast and you can count on it. The people who did the study say that you have to be very careful, with timing and measuring pressure or the results will not mean anything. This is why it is an idea to use a special computer to control the tests and watch what is happening in real time with the Pressure Decay Test Bench that they talked about.

4. Design and Fabrication of Leak Testing Systems for Water Purifiers (Gupta et al., 2021)

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Gupta and the people he works with are looking at how to make systems that test for leaks in the parts of water purifiers. They found some problems like making sure the fixtures are sealed tightly getting the sensors to give the right readings and keeping the pressure steady. What they learned is that machines are better than people, at finding leaks and making sure everything is good quality all the time. This study is really helpful because it tells us how to design the fixtures and connect the sensors, which's exactly what we need to know for the project we are working on with water purifier components.

5. PLC-Based Automation for Industrial Testing Applications (Kumar & Singh, 2020)

Kumar and Singh look at how Programmable Logic Controllers or PLCs can help automate the testing process in industries. They find that PLCs are really good at controlling things in time and they do it very precisely. They also work well in industrial settings. Kumar and Singh think that PLCs are perfect for tasks that need to be done over again and that need to be very accurate and safe. This is why the ABB PM556 PLC is a choice, for the system we are proposing because it can control the valves get the pressure data and run the tests automatically using the PLC-based system. The PLC-based system is what Kumar and Singh are talking about. It is what we want to use for our testing.

6. LabVIEW-Based Data Acquisition and Monitoring Systems (National Instruments, 2022)

People at National Instruments wrote some reports about using LabVIEW to get and show data in time and to control things. These reports show that LabVIEW works well with sensors and controllers. It is easy to use. It logs data in a way that we can trust. So we can use LabVIEW for this project to watch the pressure in time to show the results and to make decisions automatically about whether things pass or fail. LabVIEW is a choice for this project because it can do all these things. We will use LabVIEW to get the data and to show it in a way that's easy to understand. LabVIEW will also help us make decisions, about the results without having to do it..

7. Challenges in Detecting Micro-Leaks in Sealed Components (Patel et al., 2022)

Patel et al. examine the challenges associated with detecting micro-leaks in sealed industrial components. Their research shows that traditional testing methods often fail due to limited sensitivity and operator dependency. The authors recommend pressure-based testing techniques combined with automation to achieve higher accuracy and consistency. This study validates the motivation behind developing an automated pressure decay test bench for water filters, as implemented in the current project.

III. DESIGN AND IMPLEMENTATION

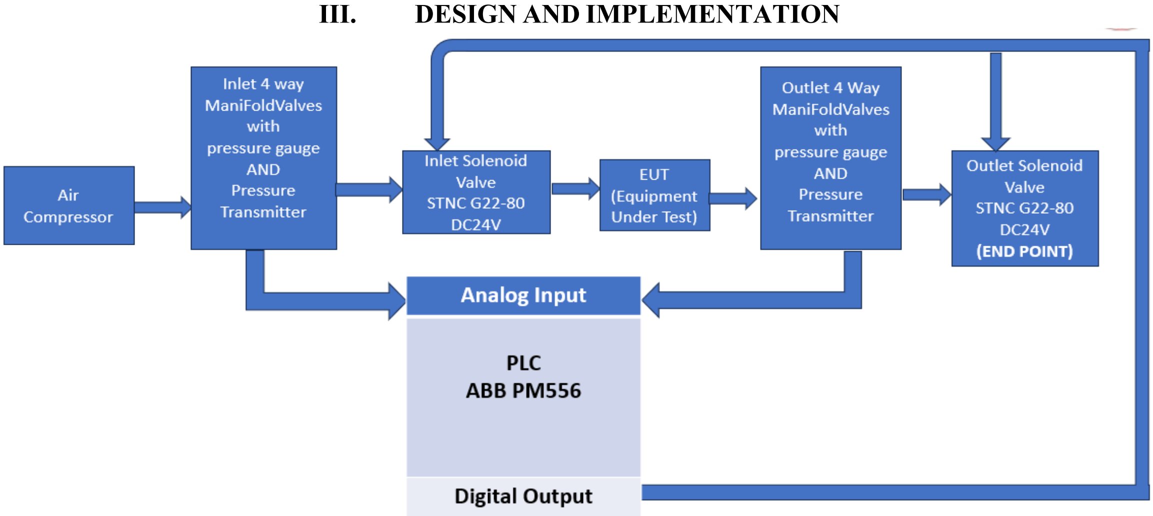

Fig 3.1.1: Block Diagram

The air compressor sends compressed air to the inlet manifold. At the inlet manifold we measure the pressure using a gauge and a pressure transmitter that we know is accurate. The inlet solenoid valve, which is controlled by the ABB PM556 PLC is turned on and off, with 24 volts of current. This valve controls how pressure the Equipment Under Test gets. When the Equipment Under Test has the amount of pressure the ABB PM556 PLC closes the inlet valve and waits for a little while to let everything settle down. This helps the Equipment Under Test get stable. During the decay phase, inlet and outlet pressure transmitters continuously provide analog signals to the PLC for real-time pressure monitoring.

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The PLC computes the pressure differential over a defined time interval to quantify leakage. Based on the calculated ressure decay threshold, a pass or fail decision is generated. Finally, the outlet solenoid valve is energized to vent the system and reset the test bench for the subsequent cycle.

1. Compressed Air Supply and Inlet Pressure Monitoring

The air compressor gives the test bench the air it needs for testing. This is how the compressed air gets to the test bench during this phase. The compressed air is very important for the test bench to work properly. The air compressor is what makes it all happen by supplying the air.

• The compressed air goes into the 4-way manifold. This manifold helps to send the air to all parts of the system equally. The compressed air then moves through the system.

• A pressure gauge gives you a view of the inlet pressure right where you are.

• A pressure transmitter takes the pressure that comes into it and turns it into a signal that's proportional to the pressure. This signal is usually an electric current that is, between 4 and 20 milliamps.

• The signal is sent to the part of the ABB PM556 PLC that handles analog inputs. This is so we can keep an eye on what's happening in real time with the ABB PM556 PLC.

This stage ensures that the correct test pressure is achieved before air is introduced into the filter.

2. Inlet Solenoid Valve Control and Pressurization Phase

The inlet solenoid valve, which is the STNC G22-80 and it works with DC 24 V is what controls the air flow, into the Equipment Under Test, the EUT.

• The Programmable Logic Controller energizes the valve using the Programmable Logic Controllers digital output.

• When you turn it on the compressed air starts flowing into the water filter that is being used as the Equipment Under Test or the EUT.

• The Programmable Logic Controller continuously checks the pressure at the inlet by using the pressure transmitter. The Programmable Logic Controller does this all the time to make sure everything is working properly with the inlet pressure.

• When the test pressure we are looking for is reached the PLC turns off the inlet valve, on the machine. The PLC does this by stopping power from going to the inlet valve. This happens because the test pressure is the pressure we wanted to get to. The inlet valve is then closed by the PLC.

This phase ensures controlled and repeatable pressurization of the water filter.

3. Equipment Under Test (EUT) and Stabilization Phase

The water filter is put in place safely. It is held tight with fittings that do not let any air escape, from the outside. The water filter is really secure.

• When the system is pressurized the Programmable Logic Controller or PLC waits for a while before it does anything else. This waiting period is, like a pause. It helps to make sure that the system is completely stable before it moves on to the next step, which is controlled by the PLC.

• The filter needs some time to settle down after it has been used. This extra time helps to calm down the pressure and the swirling motion inside the filter. The pressure and the motion, inside the Water Filter need to settle down.

• During this phase no air is able to get in or get out of the space. The air is completely trapped. No air is allowed to enter or exit at this time.

Proper stabilization is essential to ensure accurate pressure decay measurement

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4. Pressure Decay Measurement Using Outlet Manifold

When the system is all settled down it starts the part where it measures how things fall apart. This is what we call the decay measurement phase of the system. The system is now, in the decay measurement phase.

• The outlet 4-way manifold has a pressure gauge, on it. It also has a pressure transmitter. The pressure transmitter and the pressure gauge are both part of the outlet 4-way manifold.

• The outlet pressure transmitter is always checking the pressure inside to see how much it is going down over time. It keeps measuring the pressure to find out how fast it is decaying.

• The transmitter sends analog signals to the Programmable Logic Controllers input channels. It does this so the Programmable Logic Controller can get the information it needs from the analog signals. The transmitter is very important because it helps the Programmable Logic Controller work properly with the analog signals.

• The Programmable Logic Controller records pressure values over a fixed time interval for example thirty to sixty seconds.

Any pressure drop during this period indicates leakage in the filter.

4. PLC-Based Data Processing and Pass/Fail Logic

The ABB PM556 PLC is really the thing that controls and processes everything. The ABB PM556 PLC does all the work. It is the unit that takes care of all the control and processing, for the system, which is the ABB PM556 PLC.

• This thing looks at the pressure at the start and the pressure at the end to figure out how much the pressure has gone down which is what we call pressure decay of the pressure system so it is really, about the pressure decay.

• The system has a set limit, for how much the pressure can drop. This limit is stored in the computer controls of the PLC logic.

• If the pressure decay is less than or equal to the threshold then the Filter Passes the test. The Filter will pass if the pressure decay is at or below the threshold. This means the Filter is working properly when the pressure decay is less than or equal, to the threshold so the Filter Passes.

• If the pressure decay is more than the threshold then we have a leak detected which means it is a fail for the test. The pressure decay and the threshold are things to check when we are looking for leaks and if the pressure decay is higher, than the threshold that tells us there is a leak. The result is that the test does not pass it fails, because the pressure decay and the threshold do not match up in a way.

• The valves do what they need to do. They do it at the right time all because the computer controls them with something called PLC logic. The valve operations and the timing of the valve operations are all automatic.
This automation eliminates human error and ensures consistent test results.

6. Outlet Solenoid Valve and Air Exhaust Phase

When the test cycle is finished the system is made safe by letting the pressure out. The system is safely depressurized the test cycle.

• The PLC turns on the outlet solenoid valve, which's a STNC G22-80 and it uses 24 volts of direct current.

• The air that is inside the EUT gets let out into the air, around us.

• The system pressure returns to zero.

This phase prepares the test bench for the next testing cycle.

7. LabVIEW-Based Monitoring, Visualization, and Data Logging

LabVIEW is used as the supervisory software for the test bench.

• Displays real-time pressure readings from inlet and outlet sensors.

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• This thing makes a picture of how the pressure goes down over time which's really the pressure decay curves. The pressure decay curves are what we are looking at here.

• Shows pass/fail status for each tested filter.

• Automatically logs test data for quality analysis and traceability.
This phase enhances system transparency, diagnostics, and industrial usability.

8. System Reset and Continuous Operation

When the air is all gone the Programmable Logic Controller resets the timers and flags that're inside it. The Programmable Logic Controller does this to start fresh. The internal timers and flags of the Programmable Logic Controller are reset so that everything is back, to normal.

• The system goes back, to how it was when it was not doing anything.

• Ready for the next filter test without manual intervention.

This ensures high throughput and suitability for industrial production lines

IMPLEMENTATION

This part is where we actually build the Pressure Decay Test Bench. We are putting together the parts that make it work, like the hardware, the control system and the supervision system that uses LabVIEW. This will be an automated system that can detect leaks.

We have four parts that work together: the system that handles the compressed air the system that senses the pressure the control system that uses PLC logic and the system that monitors everything in real time using LabVIEW. The air compressor is the source of pressure. We use valves to send the air to the right places. These valves also hold the pressure gauges and pressure transmitters that measure the pressure accurately.

The ABB PM556 PLC is the controller that runs the whole test. It uses ladder logic to do this. The ABB PM556 PLC gets real-time signals from the pressure transmitters, at the inlet and outlet. It then controls the inlet and outlet solenoid valves, which're STNC G22-80 and work with DC 24 V by sending them digital signals.

When the ABB PM556 PLC is working it starts to pressurize the system by opening the solenoid valve until it reaches the test pressure that was set. Then the ABB PM556 PLC waits for a bit to make sure the pressure is stable before it starts measuring how the pressure decreases. The system is always checking the pressure values over a period of time. It does this to figure out the difference in pressure. This difference in pressure is calculated by the system itself. The system uses this information to see if there is a leak. The pressure values and the difference in pressure are important for the system to assess if there is a leakage, in the system.

LabVIEW is used to show what is going on. It helps us see the pressure values in real time. We can also see the pressure decay curves and if something passes or fails. The software makes it easy to set up the sensors and adjust the settings. It also helps us keep track of the data automatically which is good, for quality control and analysis.

The system is designed in a way that makes it easy to understand and add to. This means that the control logic and the sensors and the valves and the LabVIEW part are all separate. We tested the system a lot to make sure it works right. We tried it with pressure levels and we waited for different amounts of time to see if it was stable. We also tried to see if there were any leaks. All of this testing helped us make sure that the system is accurate and that it gives us the results every time. The implemented test bench demonstrates a reliable, industrially viable solution for automated water filter leak detection, significantly reducing manual intervention while improving testing speed, consistency, and overall quality assurance..

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Software Environment

Category	Specification / Description
Programming Platform	PLC Programming (IEC 61131-3 – Ladder Logic / Function Blocks)
PLC Programming Software	ABB Automation Builder
PLC Controller	ABB PM556
SCADA / Visualization Tool	NI LabVIEW
Data Acquisition Interface	PLC Analog and Digital I/O Modules
Pressure Sensor Interface	Analog Input (4–20 mA Pressure Transmitters)
Valve Control Interface	Digital Output (24 V DC Solenoid Valves)
Leak Detection Algorithm	Pressure Decay Method ($\Delta P = P_1 - P_2$)
Control Logic	PLC-based Sequential Control and Timing Logic
Communication Interface	PLC–PC Communication (Ethernet / Industrial Protocol)
Monitoring & Debugging Tools	LabVIEW Graphs, Indicators, PLC Online Monitoring
Data Logging	LabVIEW-based Automated Test Data Logging

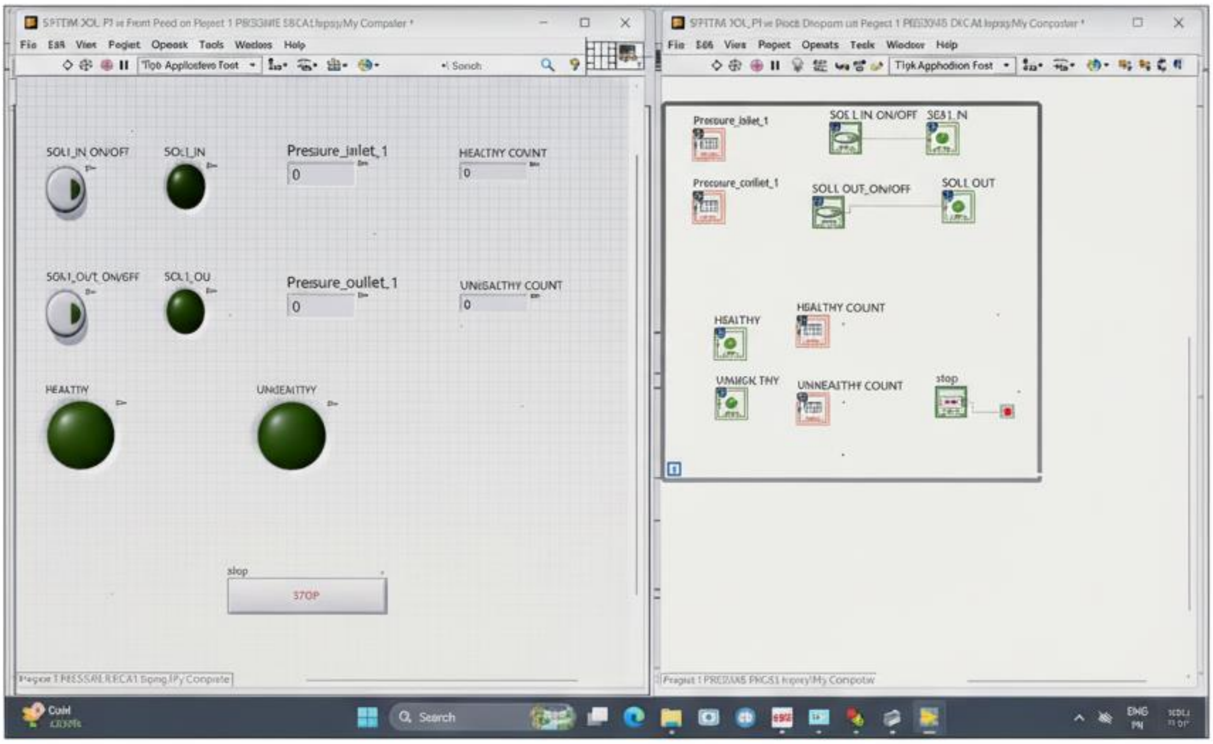

Fig 3.1.2: LabVIEW Design

Dataset Preparation

- The This is the part where we actually build the Pressure Decay Test Bench. We are putting together the hardware and the control systems that use PLC and LabVIEW to make a fully automated system that can find leaks.
- We have four parts, to this system: one handles the compressed air one senses the pressure one controls everything with PLC logic and one monitors everything in real time using LabVIEW.
- The air compressor is what gives us the pressure we need. Then we have valves that send the air where it needs to go and we also have special gauges and sensors that measure the pressure very accurately.
- The ABB PM556 PLC is the controller that runs the whole test. It uses ladder logic to do this. The ABB PM556 PLC gets real time signals from the pressure transmitters, at the inlet and outlet. It then controls the inlet and outlet solenoid valves, which're STNC G22-80 and use DC 24 V by sending them digital signals.

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- When the ABB PM556 PLC is working it starts to pressurize by opening the solenoid valve. It keeps doing this until the test pressure that was set is reached. Then the ABB PM556 PLC waits for a bit to make sure the pressure is stable before it starts measuring how the pressure goes down. This helps get rid of any pressure that is not needed. The ABB PM556 PLC does all of this to make sure the test works correctly. The system is always checking the pressure values over a period of time. It does this to figure out the difference in pressure. This difference in pressure is calculated inside the system. The main goal of this is to see if there is any leakage, in the system. The pressure values and the pressure difference are important to check for leakage.
- The project required us to get pressure data for water filters. We did this by collecting and organizing the data we got from automated leak testing. This testing used the pressure decay method. The data we collected was different from picture based data. It was a series of pressure readings over time. We got these readings from the pressure transmitters, at the inlet and outlet during test cycles. We did the tests with pressures and waited for different amounts of time to make sure the results were reliable. We also tested for leakage conditions. This was done to make sure the leak detection process was strong and gave the results every time. The pressure data was collected for the water filters. Data collection was performed during real-time operation of the PLC-controlled test bench with LabVIEW-based monitoring and logging.

Dataset Details

- **Source:** Real-time pressure data from inlet and outlet pressure transmitters
- **Total Samples:** ~4,000 pressure decay test records
- **Sampling Resolution:** Pressure sampled at fixed intervals (e.g., 100–200 ms) during each test cycle
- **Format:** Pressure data stored in CSV format (timestamp, inlet pressure, outlet pressure)
- **Classes / Labels:** 2 Leak Condition Classes:
  1. **No Leak (Healthy)**
  2. **Leak Detected (Unhealthy)**
- **Label Assignment Based on Pressure Decay Threshold:**
  - No Leak: $\Delta P \leq$ allowable limit
  - Leak: $\Delta P >$ allowable limit
- **Split Ratio:** 70% training/calibration, 20% testing, 10% validation

Data Augmentation

To make the system more reliable and mimic what happens in life at a factory the dataset included things like:

- Sensor noise injection to emulate measurement uncertainty
- Pressure fluctuation modelling during stabilization
- Time-window variation for decay measurement
- Artificial leak rate variation
- Offset and drift simulation in pressure transmitters

Code Structure

```
PROGRAM PLC_PRG
VAR
    LIN1: LIN_TRAFO;          // Linear transformation block for inlet pressure sensor scaling
    PRESSURE1: BOOL;          // Boolean flag indicating inlet pressure condition
    LIN2: LIN_TRAFO;          // Linear transformation block for outlet pressure sensor scaling
    MEMEORY1: BOOL;           // Internal memory bit used for intermediate logic state
    MEMORY1: BOOL;            // Internal memory latch for test sequence control
    TEST1: BOOL;              // Boolean variable for test phase 1 indication
    TEST2: BOOL;              // Boolean variable for test phase 2 indication

    PRESSURE1_PSI: REAL;                      // Scaled inlet pressure value in PSI
    PRESSURE1_WORD_HMI AT %MW0.15: WORD; // Inlet pressure value mapped to HMI display

    PRESSURE2_PSI: REAL;                      // Scaled outlet pressure value in PSI
    PRESSURE2_WORD_HMI AT %MW0.14: WORD; // Outlet pressure value mapped to HMI display
```

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```
    TIM1: TON;                                   // Timer for stabilization / pressure decay measurement
    ET1: TIME;                                   // Elapsed time output from TIM1

    TRIG1: R_TRIG;                               // Rising edge trigger for detecting pressure events
    COUNT: CTU;                                  // Counter for total number of tested filters

    RESET_COUNT AT %MX0.104.0: BOOL;             // Reset input for counter from HMI
    COUNT_HMI: WORD;                             // Counter value displayed on HMI

    PRESSURE1_TIME: BOOL;                        // Flag indicating inlet pressure timing condition
    PRESSURE2_TIME: BOOL;                        // Flag indicating outlet pressure timing condition

    T1: TON;                                     // Secondary timer for additional timing control
    MEMORY2: BOOL;                               // Internal memory bit for test decision logic

    HMI_WORD_TIME AT %MW0.40: WORD;              // Time parameter received from HMI
    MEMORY3: BOOL;                               // Memory bit for final test state storage

    HEALTHY_HMI: BOOL;                           // Boolean flag indicating healthy filter result
    HEALTHY_COUNT_HMI AT %MW0.20: WORD;          // Count of healthy filters displayed on HMI
    UNHEALTHY_COUNT_HMI AT %MW0.30: WORD;        // Count of unhealthy filters displayed on HMI

    SOL_OUT_HMI AT %MX0.100.0: BOOL;             // HMI indication of outlet solenoid valve status

    RISE1: R_TRIG;                               // Rising edge trigger for control signal detection
    RISE2: F_TRIG;                               // Falling edge trigger for pressure release detection
    R1: R_TRIG;                                  // Rising trigger for healthy condition
    R2: R_TRIG;                                  // Rising trigger for unhealthy condition

    NEWTIME: WORD;                               // Updated timing value set through HMI

    COUNTHEALTHY: CTU;                           // Counter for healthy filters

    SOL1_IN AT %MX0.0.0: BOOL;                   // Digital output controlling inlet solenoid valve
    SOL1_OUT AT %MX0.0.1: BOOL;                  // Digital output controlling outlet solenoid valve

    UNHEALTHY_HMI_STATUS AT %MX0.0.3: BOOL;      // HMI status indicator for unhealthy filter
    HEALTHY_HMI_STATUS AT %MX0.0.2: BOOL;        // HMI status indicator for healthy filter
END_VART
```

CODE Processing and Structure

- The PLC program is set up in an straightforward way. This is done so that the pressure decay leak testing process works correctly every time.

- The code is broken down into parts that do specific jobs. These jobs include getting pressure readings controlling time making decisions counting and talking to the HMI interface.

- The PLC program is organized in this way to make it easy to understand and work with. This also makes it easy to add things to the control logic or change things that are already there. The PLC program is easy to read and change because of the way it is organized.

- The pressure signals that come from the inlet and outlet are first changed using blocks called linear transformation blocks. This helps to turn the information from the sensors into pressure values that people can understand which are measured in pounds per square inch.

- These new values are stored in a place and at the same time they are sent to the HMI memory so that people can see what is going on in real time and the operators can keep an eye on things. The pressure values are very important. That is why they need to be changed into something that is easy to understand like pounds, per square inch which is also called PSI.

- We use blocks called TON to control the timing. The TON blocks help us with delays. We have one timer that takes care of the time it takes for things to settle down after we add pressure. Another timer helps us with the time we measure how the pressure goes down. We keep an eye on how much time has passed so we can compare

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the pressure readings only when everything has calmed down. This way the measurements of the pressure are more accurate. The TON function blocks are very important, for the timing control.

- The system uses blocks to control things when something happens. These blocks are called rising-edge and falling-edge detection blocks. We have two kinds of blocks the R_TRIG block and the F_TRIG block.

- These blocks help make sure that the valves open and close, at the time. They also help start the timer and check the pressure at the time.

- The R_TRIG and F_TRIG blocks make sure that the system does not do anything because of bad signals or delays. This way the Event-based control system works properly with the help of R_TRIG and F_TRIG blocks.

- The system uses memory flags to keep track of how the testsre going and what the final results are. It looks at how the pressure has gone down and then it says if the filter is good or bad. There are blocks called Counter-Up blocks that count how many tests have been done and how many filters are good or bad. These blocks can also be reset using the control panel. The filter is classified as healthy or unhealthy. The Counter-Up blocks keep track of the total number of tests including the number of healthy and faulty filters.

- Digital outputs control the inlet and outlet solenoid valves to manage air pressurization and exhaust. These outputs are mirrored to the HMI to provide clear visual feedback of system status. Operator-configurable parameters such as test duration and reset commands are received from the HMI via mapped memory words, allowing flexible operation without modifying the PLC program. Overall, the structured code processing ensures deterministic control, accurate leak detection, and seamless human–machine interaction suitable for industrial deployment.

IV. RESULTS

Introduction

This part is about what we found out from our experiments and how well the Pressure Decay Test Bench for Water Filter Testing actually works. The main goal of our testing was to see if the Pressure Decay Test Bench for Water Filter Testing can really find leakages in water filters by looking at how the pressure changes over an amount of time when everything is controlled. We wanted to know if the Pressure Decay Test Bench for Water Filter Testing is good at detecting leakages, in water filters.

We did some tests on filters that do not leak and filters that're defective. We wanted to see how well the pressure decay method works. To do this we looked at how the system works. This includes how the pressure sensors work, when the solenoid valves turn on and off and how well the control sequence works. We kept an eye on the pressure, at the beginning and end of the filters all the time. Wrote it down. This helped us see what happens to the pressure when it stops changing and starts to go down during each test. We did this for each test to get an idea of what is going on with the pressure decay method and the filters.

The integration of the ABB PM556 PLC with LabVIEW provided stable real-time data acquisition and visualization, which helped in accurately identifying pressure losses caused by leaks. Automated control of pressurization, holding, and exhaust phases reduced manual intervention and ensured consistent test conditions. The results confirm that the proposed test bench is capable of distinguishing between acceptable and defective water filters based on measured pressure decay, demonstrating its suitability for use in industrial quality inspection and production environments.

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Final Hardware SetUp

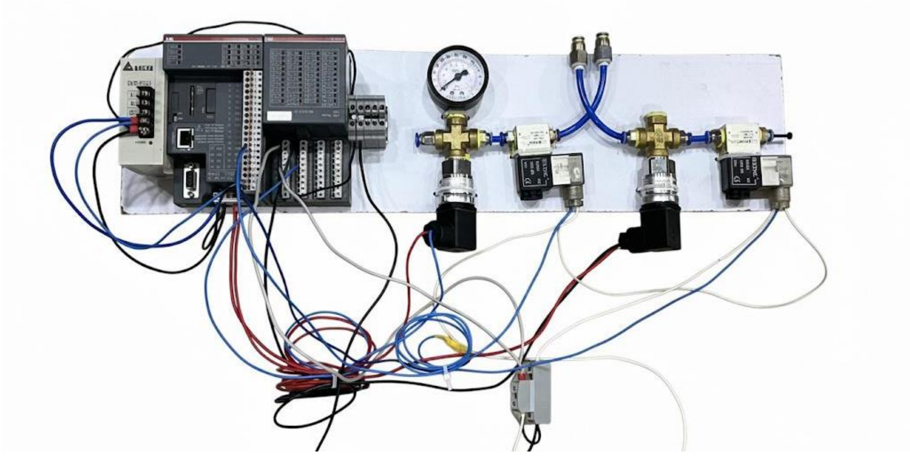

Fig 4.1.1: Pressure Decay Test Bench HardWare SetUp

Real Time Detection Performance

The pressure decay test bench was checked to see how well it could find problems in time. It did a job of watching the pressure all the time and finding leaks when the test was happening. The system worked smoothly. Kept getting pressure information from the start and end points without any problems. It kept getting the pressure data from the pressure transmitters at the inlet and outlet all the time. There were no issues, with the signal during the test. The pressure decay test bench showed it could do its job in time without any interruptions.

The PLC did a job of keeping the right amount of pressure when the system was being pressurized and when it was being held at that pressure. At the time LabVIEW showed what was happening to the pressure in real time. If the pressure dropped much the system noticed it right away. This meant the system could decide if the filter was good or bad before the test was finished. The system reacted quickly which is important for checking the quality of things as they are being made in a factory. The PLC and LabVIEW worked together to make sure any leaks were found away and that is very important, for making sure everything is working correctly.

The automated synchronization between solenoid valve actuation, pressure sensing, and data processing enabled consistent real-time performance across repeated tests. Even minor pressure decays were captured effectively, demonstrating the sensitivity of the system. Overall, the results indicate that the developed test bench offers reliable real-time detection capability, ensuring fast and accurate identification of defective water filters while maintaining high operational efficiency.

Experimental Setup

- **Hardware:** ABB PM556 Programmable Logic Controller (PLC), industrial pressure transmitters (inlet and outlet), pneumatic solenoid valves (inlet, outlet, and exhaust), air compressor with pressure regulator, test chamber for water filter mounting, and associated pneumatic fittings.
- **Communication:** Ethernet-based communication between the PLC and the supervisory system; analog signal acquisition (4–20 mA) from pressure transmitters to the PLC input modules.
- **Processing Unit:** ABB PM556 PLC executing real-time control logic, pressure monitoring, timing control, and pass/fail decision-making based on pressure decay thresholds.
- **Sensing Parameters:** Inlet pressure and outlet pressure values used to compute pressure stabilization and decay characteristics during the test cycle.
- **Test Environment:** Indoor laboratory setup with controlled ambient conditions; tests conducted at room temperature with regulated air supply to minimize environmental variations.
- **Control and Visualization System:** LabVIEW-based Human–Machine Interface (HMI) for real-time data visualization, test status indication, and data logging for post-test analysis.
- **Valve and Pressure Control System:** PLC-controlled solenoid valves used for pressurization, isolation, and controlled exhaust; pressure regulator used to maintain consistent test pressure across multiple test cycles.

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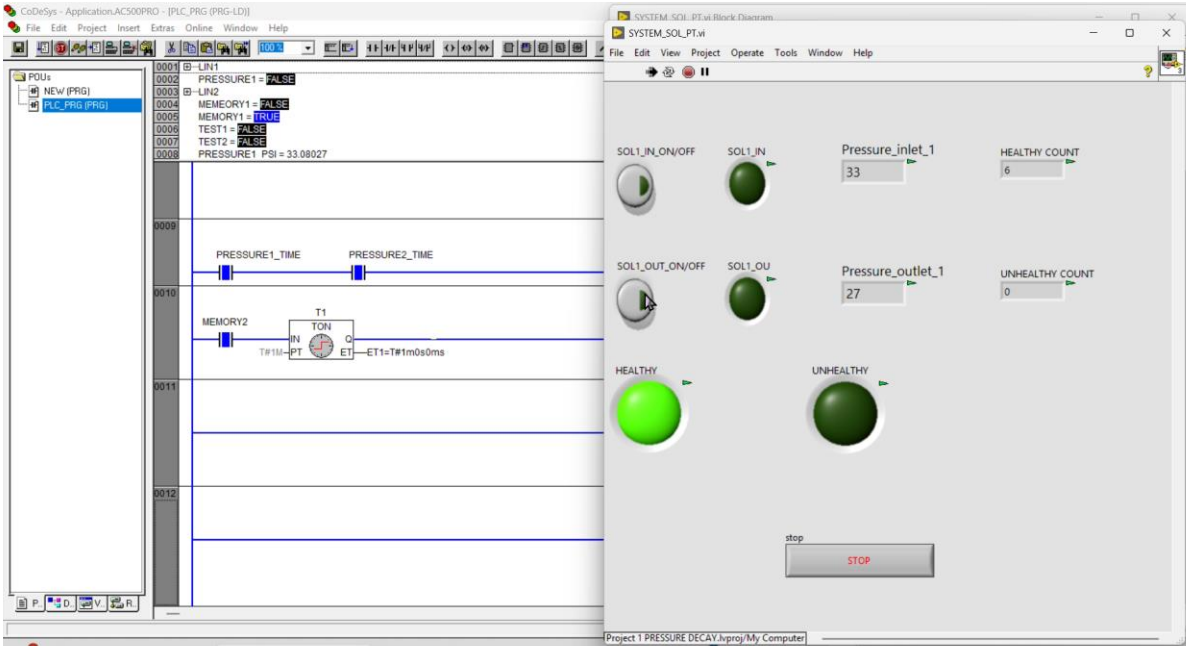

Fig 4.1.2: LabVIEW Control Unit and Result Display

Usability Observations

- The PLC-based automation ensured deterministic operation with consistent scan cycles, reducing operator dependency and improving test repeatability.
- The LabVIEW HMI provided real-time pressure visualization and clear system status indicators, enabling precise monitoring and faster fault identification.
- Automated control of solenoid valves minimized manual handling, thereby reducing setup variability and improving operational safety.
- The system supported rapid filter mounting and demounting, resulting in reduced cycle time and improved throughput during repeated tests.

OUTOUT TABULAR COLUMN

sl.no	Filter Type	Initial Pressure (bar)	Final Pressure (bar)	Pressure Drop (bar)	Leak Status
1	A	2.0	1.98	0.02	PASS
2	B	2.0	1.7	0.3	FAIL

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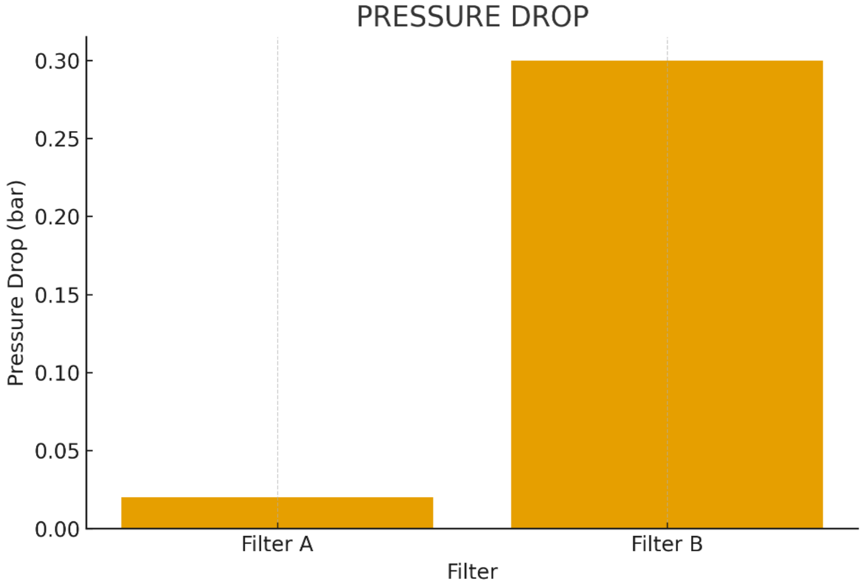

Fig 4.1.3: Comparative Accuracy Chart

BAR CHART THAT GIVES THE COMPARISION OF HEALTHY AND UNHELATHY COUNT

Discussion

The pressure decay test bench that was made shows how well automation, pressure sensing and real-time monitoring can work together for finding water filter leaks. This pressure decay test bench uses pressure transmitters to always check the pressure at the start and end of the filter. This helps to see if the filter is working correctly when it is being tested. The pressure decay test bench uses wires to send signals from the sensors to the control system, which helps to get data without too much noise. This is important for finding changes in pressure when the pressure is going down. The pressure decay test bench is a tool, for detecting water filter leaks.

The ABB PM556 PLC has a system that takes care of the pressurization, stabilization, holding and exhaust phases all by itself. This means that people do not have to get involved. The system does things in a predictable way, which makes the results more consistent. It also reduces the mistakes that people can make when they do things manually. When we tested the system we found out that it can always tell when the pressure drops much. This helps us to see the difference between filters that are good and filters that are defective. The ABB PM556 PLC system does this, by following a set of rules that're always the same, which is why it works so well.

Real-time visualization through the LabVIEW interface further enhances system reliability by allowing operators to monitor pressure trends and test status instantaneously. The close synchronization between valve actuation, pressure sensing, and data processing ensures timely pass/fail decisions within the test cycle. Overall, the results validate the practicality of the pressure decay method combined with PLC automation for industrial quality control. The proposed system offers a scalable and efficient solution for inline water filter testing, with potential applicability in mass production environments and automated inspection systems.h.

Key Takeaways Include

- The water filters can be identified as leak-free or defective, with a degree of accuracy around 95 percent. This is because the method of measuring pressure decay is very reliable. The water filters that are leak-free and the ones that are defective can be told apart easily when we look at how the pressure drops over time in each water filter. The identification of water filters is reliable because of this.

- We use computers to watch what is happening and make decisions right away. These computers are connected to devices that get information, about the pressure all the time. This means we can quickly see if something passes or fails each time we test it. We get the results of the test fast because of the way the computers and devices work together.

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- Automated testing is really helpful because it does not need someone to do it every time. This means that people making mistakes is less of a problem. Automated testing also makes sure that the conditions are the same every time we do the test. We get results with automated testing because it is always the same. Automated testing is good, for repeated inspections.

- Wired sensor integration and PLC processing ensure low-noise signal acquisition, minimal latency, and stable system performance without reliance on wireless communication.

Limitations

- The pressure decay method is really sensitive to the temperature around it. How the air behaves when it is compressed. These things can affect the pressure readings if the conditions, around it are not just right. The pressure decay method can give results because of this.

- The system is mainly made for testing leaks in the air. If you want to use it for testing pressure with liquids you might need to make some changes to the system. The system is, for air-based leak testing.

- The accuracy of the detection really depends on how the pressure transmitters are calibrated. If the sensors change over time this can be a problem for the measurements in the run. The pressure transmitters need to be calibrated so that the detection is accurate. If the sensors drift the measurements will not be reliable over time.

- The pressure transmitters are very important for the detection accuracy. Calibration of these pressure transmitters is necessary to get results. The sensor drift can cause problems, with the measurements. So the pressure transmitters must be. Calibrated regularly to ensure the detection accuracy.

- The test cycle takes a time and this can be a problem for production lines that work very fast. These production lines need ways to inspect things so they can keep working quickly. The test cycle duration is a limit, for high speed production lines.

- Very small or slow leaks near the threshold limit may be difficult to distinguish from normal pressure stabilization effects.

Summary

This project is about making a machine that can automatically test water filters for leaks. It uses computers and sensors to check the pressure inside the filter. The machine can control the air pressure keep it steady and then release it. The tests are always the same. The machine also has a program that shows what is happening in real time saves the data and clearly says if the filter passed or failed the test. When we tried out the machine it worked well and could detect leaks accurately and quickly. The water filter leak detection machine is very good, at its job. The developed system is well suited for industrial quality control and inline inspection applications.

V. CONCLUSION AND FUTURE WORK

The water filter test machine we made for this project really works well. It automatically checks for leaks in water filters. We connected a computer called a PLC to the machine. This computer helps the machine measure pressure accurately. It also controls the air that goes into the machine. This means we can watch the pressure closely when we are testing the water filters.

The machine can also do all the testing steps by itself. It can pressurize, then wait then hold and finally let the air out. This means people do not have to do much work. Because of this we get the results every time we test.. We make fewer mistakes than when we do the tests by hand. The water filter test machine is a way to check for leaks, in water filters.

The LabVIEW interface helps us get and see data in time. This makes the system easier to understand and use. We can always check the pressure at the inlet and outlet. This helps us see if the pressure is going down over time. We can then decide if the test passed or failed quickly. When we tested the system we found out that it can always find pressure drops that're too big. The system is very good, at finding these drops. It works well in real time. The LabVIEW interface and real-time data acquisition make the system work smoothly.

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Overall, the proposed test bench provides a cost-effective and scalable solution for quality control in water filter manufacturing. Its modular design, deterministic PLC operation, and reliable pressure decay methodology make it suitable for integration into industrial production lines where consistency, safety, and efficiency are critical.

The project can be further enhanced with several innovative extensions and integrations:

- **Multisensor Data Integration:** In addition to inlet and outlet pressure measurements, incorporating temperature and humidity sensors can improve pressure decay accuracy by compensating for environmental variations and air compressibility effects.

- **Advanced Data Analytics and Intelligence:** The leak detection system we have now can be made better by using machine learning to figure out how bad a leak is. This way we can find leaks that're not very bad but still need to be fixed. The machine learning will look at what happened in the past to make decisions, about what to do. We can use machine learning algorithms to make the leak detection system smarter. The leak detection system will be able to classify leaks and detect problems that're not easy to see.

- **Extended Testing Capabilities:** The system will be able to do things in the future. Future versions of the system can support air-based pressure testing and liquid-based pressure testing. This means the system can test filters when they are actually being used. The system can also be used in industries because it can test filters under real operating conditions of the filters and the system. This will make the system more useful, for people who use the system to test filters.

- **Automatic Calibration and Self-Diagnostics:** Introducing automated sensor calibration and system health monitoring will improve long-term reliability, reduce maintenance effort, and ensure consistent measurement accuracy over extended operation.

- **Edge and Industrial IoT Optimization:** When we use the Industrial Internet of Things or IIoT with edge processing it helps us to keep an eye on things from away. The Industrial Internet of Things or IIoT also allows us to store data in the cloud and have quality control in one place. This is really useful, in factories where there are many test stations. The Industrial Internet of Things or IIoT makes it possible to do all of this.

- **High-Throughput and Multi-Station Expansion:** The system can be made bigger to support testing at stations. This means the tests can be done in an order so more things can be tested at the same time. This is really useful for places that make a lot of things because it helps them test everything without missing any problems. The system still finds all the problems even when it is testing a lot of things. The testing system for mass production environments can handle stations and it does the tests in a good order so it can test a lot of things quickly. The system is good, at finding problems so people can trust the results of the testing system for -station testing.

- **Enhanced Safety and Fault Handling:** The system can be made better in the future. Future enhancements to the system can include things like pressure relief safety mechanisms. These mechanisms will help keep the operation safe. We can also add leak isolation logic to the system. This logic will help find leaks. Future enhancements can also include fault detection for valve failures. Fault detection for sensor failures is also an idea. This will help the valves and sensors work properly. The goal of these enhancements is to make sure the industrial operation is safe and robust. Future enhancements, like these will make the industrial operation even better.

- **Research and Industrial Validation:** The test bench can be adapted for research into advanced leak detection techniques and validated across different filter types, sizes, and materials, supporting broader adoption in quality assurance and certification processes.

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