DEVELOPMENT OF AN APPARATUS FOR TESTING INJECTION VALVES FOR LIQUID MOLDING APPLICATIONS

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SUMMARY

This paper deals with development of a special leak and flow test apparatus. This apparatus would be used to check the reliability and performance of an innovative pneumatically operated injection valve for liquid molding applications. Also included are the results of various tests. This design is an example of one of the author's senior project carried out to fulfill BS degree requirement.

There is an increasing trend towards the use of advanced materials, specifically, polymer composites to improve corrosion resistance and to reduce weight in structural and nonstructural components. Such components have good potential for aerospace and automotive applications. Liquid molding processes such as resin transfer molding are becoming popular for producing fiber composites of low cost tooling and processing. As a part of this project, a new self-flushing pneumatically operated valve for liquid molding applications was developed and fabricated [1]. This valve was used to replace the manual processes and old- fashioned techniques in order to maintain production quantity, increase the quality of the product, and to decrease the cycle time.

A special test apparatus was developed and fabricated to check the reliability and performance to meet the specification for leakage and fluid flow. The injection valve was attached to a panel and nylon tubing with quick disconnect pressure fittings. A solenoid was wired to a timer with on /off relay switch and was used to enable cycling of the injection valve. A main toggle switch was added to the system. A twenty-four-channel data acquisition system for pressure sensing and pressure drop assessment and a 486 CPU 166 MHz PC unit were used.

Three individual channels were used in the experimentation. The software used is an application generator Windows based program called Visual Designer that enabled real-time observation charting and data recording. The input and output ladder diagrams were programmed for the experiments to record data.

The results and discussion of the following tests are presented in this paper: air leak check in the flow position; air leak check in the flush position; water flow check in flow and flush positions; cycle test; and air leak check after cycling. This newly developed valve passed all tests and surpassed the expected outcomes.

INTRODUCTION

This paper describes a project that deals with the development and comprehensive testing of a unique, pneumatically operated injection valve for liquid molding applications. The use of composite materials is becoming more prevalent in industries such as aerospace, automotive, and recreational market sectors. Composites offer a lightweight, high strength alternative to metals by incorporating complex part geometry replacing multi-piece welded metal components.

Among current composite manufacturing processes such as liquid molding (although considered a low volume process) show potential to produce quality parts at a lower cost. Some of the major benefits of the process are the ability to incorporate higher fiber volumes, higher strength, and low cycle times.

Liquid molding is a process whereby catalyzed resin materials are dispensed into a mold cavity containing a pre-shaped fiber mat or preform. Two types of liquid molding process exist that are common in industry. Structural Reaction Injection Molding (SRIM) is a process that injects rapidly reacting urea based materials at high pressures into a fiber filled mold cavity. Another type of liquid molding is called Resin Transfer Molding (RTM) widely used in composite manufacturing [2]. Recent advances in resin chemistry and process automation have made RTM a more desirable manufacturing process [3].

Thermoset resin material such as polyester or epoxies are typically used and dispensed from a specialized pump which properly measures and delivers the components at the correct ratio to insure full cure of the resin. Although part specific, resin catalysis usually occurs within 5-10 minutes after injection. The viscosity varies in the approximate range of 200-500 centi-poise (cP) for different materials. Final mixing of the components occurs at the static mix gun. A tube is attached at the end which is usually fitted at the sprue area of the mold cavity and is held in place with a hose clamp [4]

A specialized pneumatically operated valve to eliminate the manual steps of tubing replacement has been designed, fabricated, and tested. The developed valve was covered in details in the prior publication [1].

This paper deals with development of a special test apparatus and procedure to perform various tests of the developed valve. The specific goals of this project were to develop a test apparatus with a procedure to allow the following: (1) To determine the basic characteristics of the valve i.e. flow of liquid components at an appropriate flow rate, leakage at different inlet and outlet configurations, and velocity coefficient (Cv). (2) Obtain functional performance of the valve for cycling and ability to flush the static mix head of react components to prevent gelling and hardening inside the mix head after the liquid molding process being completed. These tests were actually the key in determining whether the developed pneumatically operated injection valve satisfied the requirements and purpose of the liquid molding application.

TEST APPARATUS

A test apparatus (Figure 1) was designed and assembled to enable the injection valve to be properly leak checked and to conduct fluid flow experiments. A flat composite panel (2' x 2') was used to mount the various manual ball valves, pressure transducers, and additional hardware. The injection valve was attached to the panel and nylon tubing (1/4" diameter) with quick disconnect pressure fittings connecting various components. Three pressure transducers (Dynisco, PT-422A) were placed in-line prior to the inlet port of the injection valve and at the flow exit and flush exit sides of the valve. Additionally, manual ball valves were installed to enable flow or shut off of the air or water. The system also had a dual port solenoid air valve attached via tubing to the pneumatic drive cylinder. This solenoid was wired to a timer on/off relay switch and was used to enable cycling of the injection valve. A main toggle switch was added to the system.

Signal conditioners were employed to minimize noise in the output. The software used was an application generator Windows based program called Visual Designer which enabled real time observation plotting and data recording [5].

A twenty-four channel data acquisition system for pressure sensing and pressure drop assessment and a 486 CPU 166 MHz PC in conjunction with the unit were used. Three individual channels were used in the experiments. The input and output ladder diagram (Figure 2) was programmed for the experiments to record one data point per second and to export to ASCII format for post spread-sheet analysis.

TESTING, RESULTS, AND DISCUSSION

Several tests were performed to check the injection valve for seal integrity and assessment of flow characteristics. Prior to each test, a calibration was performed on the pressure transducers. In-line ball valves were manually turned on and off as needed.

After the injection valve was assembled, mounted, and connected to the apparatus, first of all several compressed air leak tests were performed. These tests were followed by pressure drop assessment across the valve and volumetric flow measurements using water as a working fluid. The final experiment involved cycle testing of valve to determine the real integrity over time, followed by additional air leak tests.

(a) Air Leak Test - Flow and Flush Positions:

A special fitting was attached to the base of the valve in order to test integrity of the valve stem seals. For the flow position, an air line was attached to the exit side of the valve being set in the closed position. Manual valves of the flow inlet (Valve 1) and flush exit (Valve 3) were closed in order to see a potential rise in pressure emanating from the source as shown in Figure 3. Once attached to the main compressed air source of 90-100 psig pressure, data was collected over ten minute intervals.

In the flush position (Figure 4), leak test was performed to assess potential leakage in the inlet and exit side of the valve. The exit flow (Valve 2) and exit flush (Valve 3) manual ball valves were turned off. Additionally, soapy water in both the tests was also used at the top of the valve to see if any leakage may be observed there.

The results of these tests are shown in Figure 5. They indicate that no leakage was observed during the ten-minute interval. Normal fluctuations in the shop compressed air were observed.

(b) Valve Flow Check - Flow and Flush Positions:

Two sets of experiments were carried out to assess the flow characteristics of the injection valve. The first set involved flowing tap water at a temperature of 15 C through the inlet of the valve body via the bottom of the valve commonly known as the flow position (retracted stem position) as shown in Figure 6. This would simulate the normal flow of liquid into the mold cavity during actual trial. Pressure reading across the valve were plotted and recorded for the test time of 10 minutes. Two volumetric flow rates were measure by taking a beaker sample of water at the exit side of the flush tube and subsequently recording the weight and sampling time. The process was repeated five times to determine a mean value.

A second set of experiments involved flow of water in the flush position. The results of these tests are reported in Table 1. It indicates that a high pressure drop occurs across the injection valve in the flush position as expected because of higher flow restriction. The average flow rate in the flow position is 1.09 gallon/ minute, where in the flush position the flow rate is 0.69 gallon/minute. The average velocity coefficient, Cv = 0.3573 and 0.1187 in the flow and flush positions, respectively.

(c) Cycle Testing:

The primary purpose of the cycle test was to assess the "V"-Pack Teflon seal integrity with time. To achieve this, a timer relay was installed on the test apparatus enabling an on/off cycle to be regulated between 0 and 30 seconds. The timer output was connected to a dual port air solenoid valve cycling the pneumatic drive cylinder and reciprocating the valve stem. A 5 second on/off cycle was conducted over an eight-hour period for a total of 10,000 cycles. Data was recorded at 1-second interval for the first 10 minutes of the experiment.

After the cycling experiments, the air leak checking test was performed. This test revealed that the leak integrity of the valve satisfied the requirements and a negligible rise in pressure was noted over a span of 5 minute. The initial leak checks using air unveiled that the "V"-Pack seals could withstand pressures arising from different valve stem positions.

Experiments using water were also successful and the data yielded precise measurements of flow rate and flow velocity coefficients for two flow conditions. This successful testing of the valve assembly has proven to be beneficial in understanding whether the component would be worthy of service in very demanding industrial applications.

CONCLUSIONS

Composites are being selected for their high strength to weight properties. Resin Transfer Molding (RTM) is a unique form of liquid molding and is mainly used in composite manufacturing for low to medium volume parts in aerospace, defense, and automotive markets. Advances in process techniques have made RTM a viable alternative to other processes. One innovative device is a pneumatically operated injection valve that replaces age-old practice of manually connecting a plastic hose before and after a typical cycle run. By eliminating this practice, productivity and cost savings are realized.

The developed test apparatus was used as multi-function component with three specifically placed pressure transducers and manual valves. It would serve for air leak checks, water flow determination, and cycle testing. Pressure and flow measurements were taken and tests were subsequently performed using the data acquisition system.

Results of tests indicate that the developed valve passed air leak checks at different inlet and outlet configurations. Additionally, the flow characteristics of the valve were assessed using the experimental parameters such as the velocity coefficient, flow rate, and velocity at flow and flush positions of the valve. The final test performed was the cycling test that confirmed the seal integrity over time.

This project showed that the pneumatically operated injection valve is a viable component that could be used in a production environment to further enhance productivity. This development would be very much welcome in industry.

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BIOGRAPHY OF AUTHORS

Vladimir Sheyman: Vladimir Sheyman received his Ph.D. in Mechanical Engineering from the Academy of Sciences, Minsk, Belarus. Prior to joining WSU Division of Engineering Technology in 1986, he worked in industries. His areas of interest include heat and mass transfer and thermal sciences. He has published monographs and over 90 papers, and has received patents for 27 inventions.

Mulchand S. Rathod: Mulchand S. Rathod, Ph.D., P.E. joined WSU as Professor and Director of the Division of Engineering Technology in 1987. He earned his B.E. (Mechanical) degree from Sardar Patel University in 1970; and M.S. in 1972, Ph.D. in 1975, both in Mechanical Engineering from Mississippi State University. At WSU, he has been instrumental in starting four new undergraduate and a graduate program. He established student chapters of SME and Tau Alpha Pi and is the founding leader of the Professional Order of Engineering Technology.

His prior appointments include State University of New York at Binghamton, Tuskegee University, Jet Propulsion Laboratory, and IBM. A registered Professional Engineer, he is active in ASME, SME, ASHRAE, and ASEE. He has served as a Commissioner on the TAC of ABET. A holder of numerous publications and inventions, he is listed in several Who's Who publications. He was awarded the1995 Dedicated Service Award, 1998 Ben C Sparks Medal, and 2001 BMW Award by ASME and Certificates of Recognition by NASA and IBM for technical innovation. Also, a recipient of numerous grants and contracts and a Fellow of ASME, Dr. Rathod is a nationally known leader in Engineering Technology education community.

Christopher P. Karas: Christopher P. Karas earned his B.S. in Engineering Technology degree from Wayne State University. He has been working in automotive and related industries for several years in engineering and management positions.

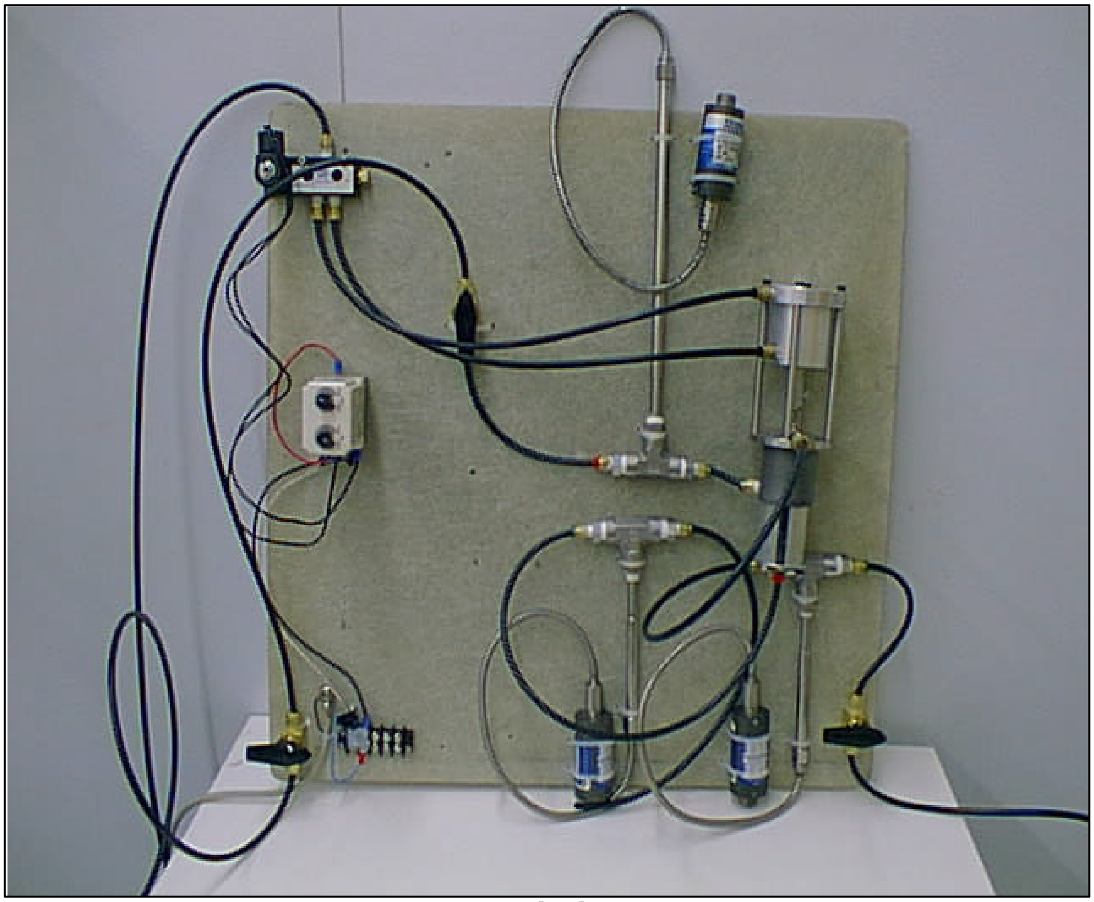

Figure 1. Leak Flow Test Apparatus

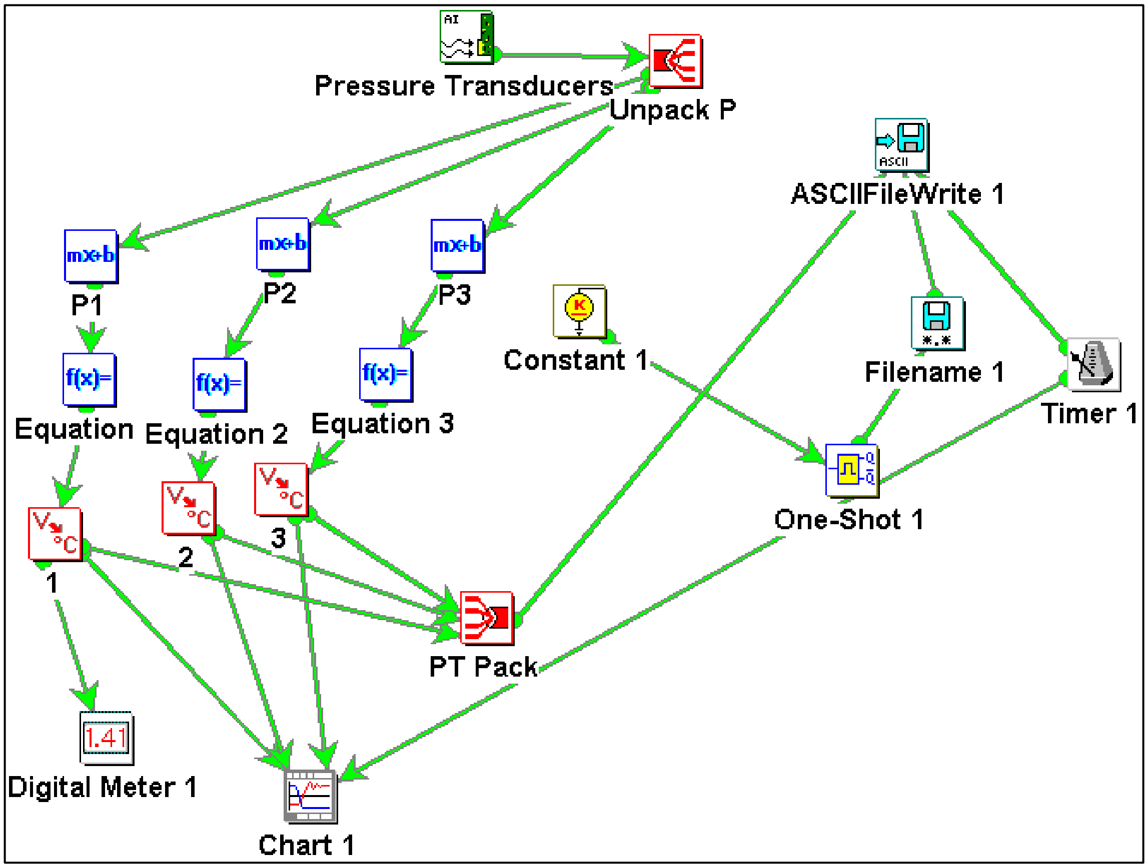

Figure 2. Application Generator Ladder Diagram

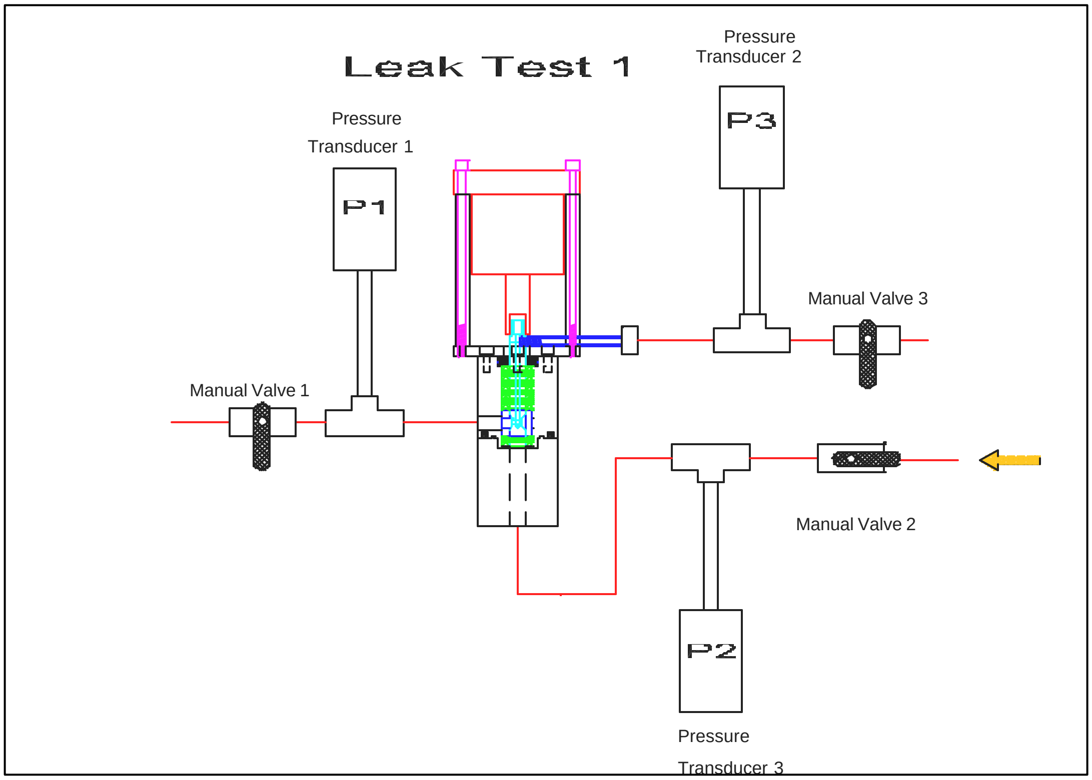

Figure 3. Leak Test 1 Schematic Diagram

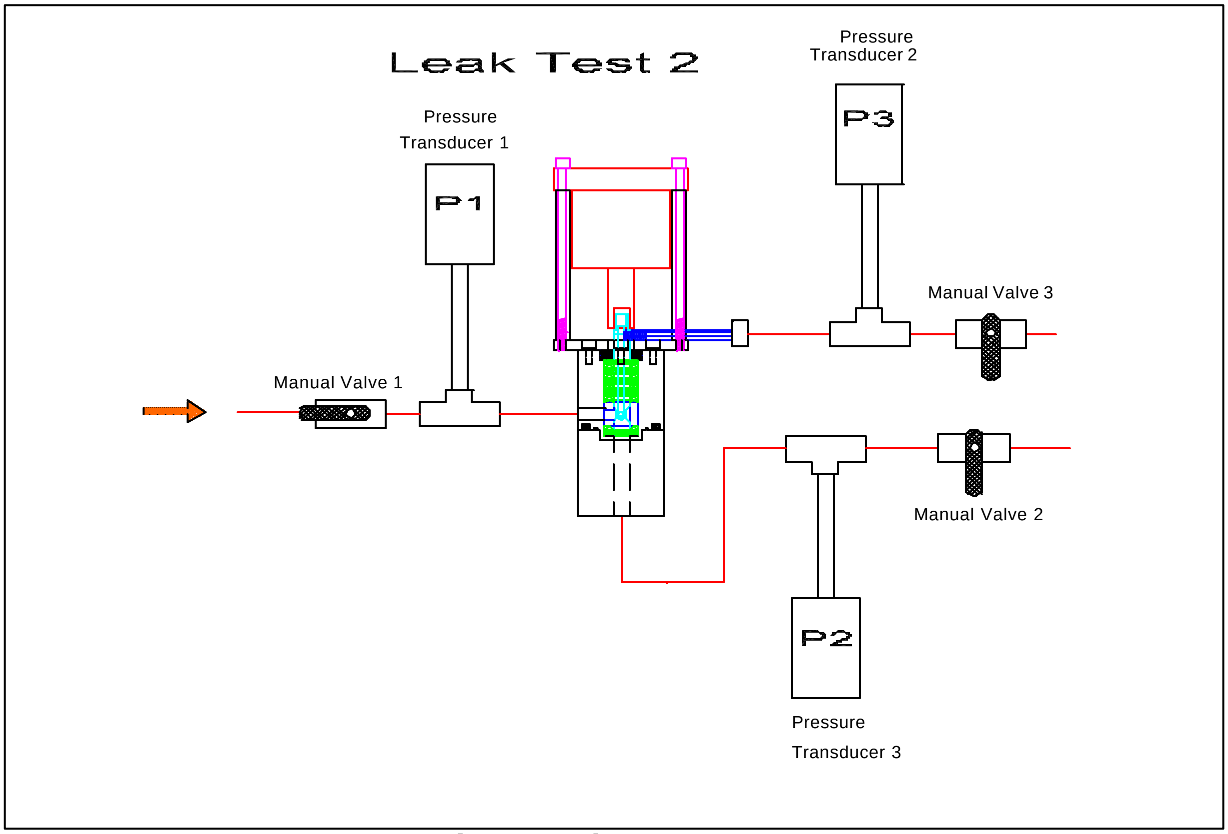

Figure 4. Leak Test 2 Schematic Diagram

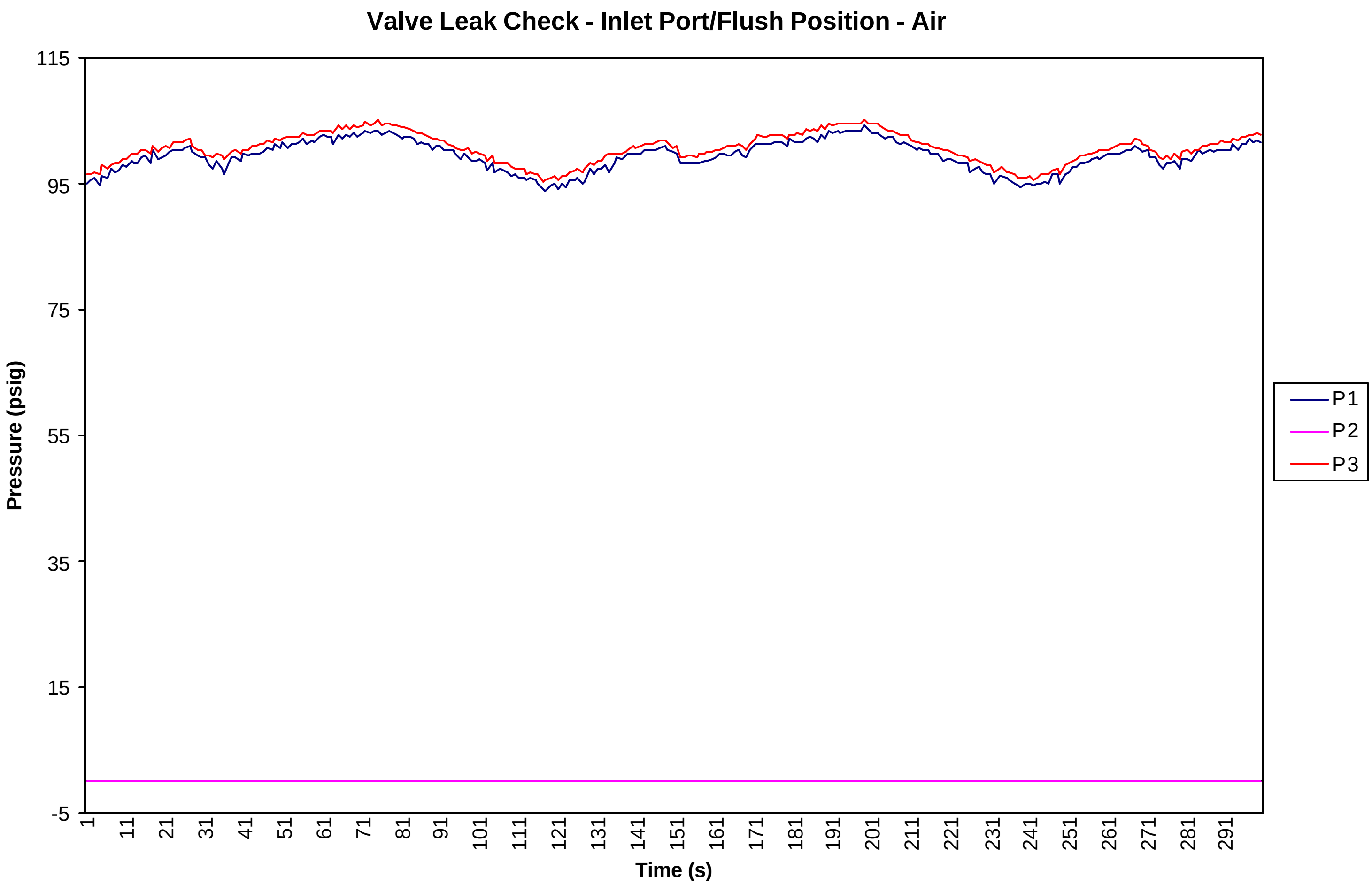

Figure 5. Leak Test for Flow Position and Flush Position

Table 1. Experimental Results

Valve Open Position							
Trial 1	Time (s)	Time (min)	Weight (g)	Volume (l)	Volume (Gal)	Flow Rate (Q)	Cv
						Gal/min	
1	7	0.1167	490.8	0.4903	0.1295	1.1103	0.3620
2	7	0.1167	475.5	0.4750	0.1255	1.0757	0.3507
3	7	0.1167	476.7	0.4762	0.1258	1.0784	0.3516
4	7	0.1167	488.8	0.4883	0.1290	1.1058	0.3605
5	7	0.1167	490.7	0.4902	0.1295	1.1101	0.3619
					Average	1.0961	0.3573
					STD	0.0156	0.0051
	P1	P2		P1	P3		
Average	30.415111	21.00561	9.409504	45.50571	11.46185733	34.04385206	
STD	0.4117246	0.569842		0.681425	0.297508794		
Valve Flush Position							
Trial 2	Time (s)	Time (min)	Weight (g)	Volume (l)	Volume (Gal)	Flow Rate (Q)	Cv
						Gal/Min	
1	10	0.1667	428.5	0.428072	0.1131	0.6786	0.1163
2	10	0.1667	434.5	0.434066	0.1147	0.6881	0.1179
3	10	0.1667	446.6	0.446153	0.1179	0.7072	0.1212
4	10	0.1667	435.4	0.434965	0.1149	0.6895	0.1182
5	10	0.1667	440.8	0.440359	0.1163	0.6981	0.1196
					Average	0.6923	0.1187
					STD	0.0097	0.0017

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