Swagelok Adjustable Check Valve Setting Device

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Recommended Citation
Sours, Brandon; Olson, Paul; Race, David; and Rimpf, Nick, "Swagelok Adjustable Check Valve Setting Device" (2018). Honors Research Projects. 659.
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Honors Senior Design Project
Swagelok
Adjustable Check Valve Setting Device

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Project Sponsor: Dr. Shao Wang
Paul Olson
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Swagelok - Solon, Ohio

04/27/18
Executive Summary

Check valves are used to control the amount of flow through a valve and only open when a certain pressure is reached. The path of the fluid is strictly in one direction, which allows the valve to prevent any back flow within a system. They are also one of few self-automated piping system components that do not require assistance to open or close. Some check valves use a combination spring-and-nut compression assembly to set an opening pressure. As the nut is used to set the spring compression, and by extension the opening pressure, problems tend to arise when adjusting the nut to the correct position for a corresponding pressure. The current testing methods take an extended period of time disproportional to the simplicity of the operation. The extensive process begins by hooking up hoses to check pressures and then detaching the same hoses to readjust. The cycle is repeated multiple times until the correct pressure has been confirmed three times. This can be very tedious work as some valves need to be set within a few pounds per square inch (PSI) leaving little room for error. Swagelok requested a new testing method be designed, whether it be a new process or fitting, to help reduce the testing time. This report contains the process the group underwent and the final design that was approved by Swagelok.
Acknowledgments

To begin, we would like to thank Swagelok, specifically Matthew Dixon and Prasanna Bhamidipati. Their guidance and the opportunity to provide a design that will possibly improve daily processes within the manufacturing line of their company is a great honor.

We would also like to thank Dr. Reza Madad, his guidance and encouragement in these pivotal semesters of our college careers has been exceptional.

We would like to thank Dr. Scott Sawyer for the knowledge he has shared in Fluid Dynamic systems as well as also agreeing to be an advisor for the project.

Lastly, we would also like to thank Dr. Shao Wang for being both an advisor for this project as well as providing a means of communication with Swagelok.
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Introduction

Background
This project is important for Swagelok because it can increase their profit margin. Current methods for adjusting these check valves involve an extended process that increases labor costs. The goal of this project is to lower these testing times. When a product is being manufactured, it is important to keep both material and labor costs in mind. Material costs can only be changed in the design. Once a design is finalized this cost is more dependent on the market and is therefore less controllable by a company. However, labor costs are purely internal and can be decreased by improving production speed. At the moment the process is quite slow, thus this project is a good starting point to improving Swagelok’s profit margin on their adjustable check valve line.

Principles of Operation
Customer Needs
- Fast and efficient way to adjust set pressures
- Low maintenance
- Ease of operation
- Reliability
- Safety

Product Specifications and Requirements
- Must be either mechanical or pneumatic
- Must fit a wide range of check valve configurations

Product Definition

Short Design Brief
The goal of this project is to design and build a prototype device that can easily and safely adjust set pressures for adjustable check valves. The device can be mechanical or pneumatic, but must handle a wide range of check valves configurations and pressure settings.

Design Brief
The goal of this project is to design an improvement to the current process of setting adjustable check valve popping pressures. The current method is conducted by attaching a hose while checking the pressure, and then detaching the hose when adjusting. The new method must either completely redesign the whole process or allow flow through the tool so that adjusting and testing can be done simultaneously. The design of the check valves cannot be altered. Methods may be either mechanical or pneumatic. An efficient, quick, and effective design that has a similar output will be conceptualized based on previous methods. This new design will be a faster and more efficient testing method that would decrease labor cost and increase profit.
Conceptual Design

The first round of conceptual design involves narrowing down ideas from brainstorming. With the restrictions in place from the design specifications, brainstorming was kept to a minimum. Each person was to come up with at least 2 brainstorming ideas, or help develop one with someone else. The ideas were as follows:

1. Angular Bracket with Cap: This design is the simplest mechanically. With adapters per each valve, only one product would be made as both sized Allen wrenches could fit in this fitting. However unscrewing the cap each time slows down the process.

2. Self-sealing Angle Bracket: While very similar to the previous design, versatility was scarified for speed. By adding a spring to use the modified Allen wrench to seal the system, this cut time by even more. While this design does require two different models as the Allen wrench is a part of the system. This could be made to be interchangeable but two Allen wrenches need to be made for the different sizes.

3. SEM nut Adjuster: This was a more complex idea allowing flow through the fitting as adjustments are being made. The nut would attach to the adapters as the tool would free spin allowing adjustments like the washer part of a SEM nut. Since the product is fused, two full prototypes would be required for the different sizes.

4. Pressure Knob: A knob would attached to an Allen wrench. As it would turn, different pressures would be displayed as presets for the location of the set nut. This would be based on the displacement that the spring would be compressed. This would then be checked using the old method for accuracy, removing a major part of the guessing from testing.

5. Torque Wrench: Similar to how a torque wrench works, the wrench won’t allow the spring to be tightened past a certain force pertaining to a given pressure. Testing would be done to consider how much the popping pressure is increased from suction.

6. Force Gage: By applying a force from the other side, the nut could be set per the result. A correlation between the popping pressure and the force read by a mechanical force gage would be required. However, it would be difficult to tell when the required force was reached.

7. Self-Automated with Star bit: This would be computer controlled. A compressor would pressurize a pressure vessel with a gage. A star bit in a hex nut will allow passage of fluid around the edges of the bit which is connected to a servo motor. An Arduino is attached to the servo motor allowing it to make the adjustments read from a change in the pressure gage. This is a costly set up but it is offset by being self-automated.
8. **Compressor Sensor**: A compressive sensor will be placed between the valve and its resting place. A digital readout would be attached to the sensor. As the nut was tightened into position, the sensor would display the required force to open the valve. Once set the sensor would be removed.

After a sufficient amount of designs were theorized, the narrowing process began. Since there were a minimal amount of designs, it was decided that a Pugh Chart was not necessary as it would only be helpful to weed out impractical ideas. The Compressor Sensor seemed to be the most costly idea as well as being impractical for the design window of the project. With this elimination, the remaining seven ideas moved to the next screening process. An Objective Tree (Figure 9) was developed based on what the team considered the most important aspects of the product. The most important factor was determined to be decreasing testing time. Once complete the Objective Tree was presented to Matthew Dixon for approval. From there, Weighted Decision Matrices (Figure 10-16) were constructed for designs one through seven. For each design, scores were discussed concerning each factor in the Objective Tree. Finally, scores were determined and the **Self-sealing Angle Bracket** had the highest score, thus ending the selection process.

**Embodiment Design**

The design of the self-sealing angle bracket must conform to certain rules and principles that guarantee the function and safety of the system. The design is safe, simple, and holds a high clarity of function. Its components are self-helping with a specific division of tasks that stack upon one another. These factors provide a degree of support to each other that brings uniform stability to the system as a whole. The angle bracket’s product architecture, configuration design, and parametric design all contribute to the product’s overall quality as well as decrease the time deficit created by testing each individual valve.

The product architecture of the self-sealing angle bracket is a simple system of connecting components. It consists of an Allen wrench, or hex key, that slides into two different externally threaded nuts inlaid within the valve. The first of these nuts is for adjusting the opening pressure while the second locks the first in place. Wrapped around the Allen key is a spring with an accompanying O-ring. As the Allen wrench is pushed down to adjust the nut, the spring compresses against the O-ring which seals the opening of the valve. The wrench will be equipped with a port for a pin to slide into on its free end. This prevents the spring from flying off the handle upon compression.

There are only a few standard components required for the bracket’s configuration design. The O-ring and spring fall into this category. Their sizes correspond to the size of the Allen wrench. As for special parts, the Allen wrench will be equipped with a pin in its free end. There are two specific sizes of Allen keys that are used to adjust and lock the nuts within the system: 5/32 inches and 5/16 inches. As testing began, new parameters were brought to light that called for a redesign of the tool.
Redesign

Due to time restrictions from the late start of the project, a T-pipe fitting was chosen instead of a custom fitting as the housing for the tool. Because a custom fitting was no longer being used it was necessary to come up with new connection methods for the spring and hex key combination. Unfortunately, no feasible method was found and a new design needed to be made. It was decided to use a rod with a hex tip and slot for airflow to adjust the nuts, and the rod was to be sealed in the T-fitting using proprietary Swagelok techniques. It was discovered during testing that the new tool did not help with the difficulty of adjusting the locking nut once the correct pressure was set, and a shaft collar and stopper clip were designed for use. With the new tool assembled and a verbal confirmation of increased ease from an operator familiar with the product, the new tool was considered a success.

Again, the embodiment rules and principles needed to be identified for the new design. The tool has a very clear function, it is simplistic in design and use, it is safe to be used while the testing apparatus is on, and it has a very minimal impact on the environment due to the lack of disposable parts. The system is considered stable as it can be easily righted after a disturbance, there is a clear division of tasks due to minimal parts, and there is a force transmission from the handle to the hex tip of the rod.

The rod was made from A2 tool steel and was manufactured on a CNC lathe. The plastic stopper clip and shaft collar were 3D printed but will eventually be made of a more permanent material. The other parts included in the assembly were either purchased or previously manufactured by Swagelok. An aluminum wing nut was purchased to secure the shaft collar to the rod when necessary, and a handle was purchased for the rod to allow for increased precision and handling. Because of the simplicity of the design, there were few types of connections used in the final assembly: threads, snap-on, quick-connect, and the proprietary Swagelok connections.

Detailed Design

As it can be seen in Figure 2 the T-fitting with attached adapters satisfies the specifications laid out by Swagelok. The assembly serves as a fitting that can be attached to any adapter on the CA and CPA valves. A rod with an Allen key tip remains in the T throughout the entire pressure setting process. The hex tip is made to ASME standard B18.3-2003 with a custom cut slot to allow airflow while the tip is inserted into the adjustment nuts. The rod is secured within the T in such a way that air does not leak out while testing is in progress. There is a custom shaft collar on the rod that is used with a custom stop clip. These two pieces were designed by the group to ensure that the rod was only removed from the adjustment nut, that way the lock nut could be secured without fear of readjusting the adjustment nut. This design only has one moving part that will be subject to wear and tear, but the effect will be minimal. In order to meet the specification of different Allen key sizes, a second rod was designed in the same fashion as the first with a different sized tip. By doing this, only one T-assembly needed to be created with the ability to interchange rods.
Discussion

Over the duration of the fall semester our senior design team met several times with Matthew Dixon of Swagelok via webcam correspondence. Through these meetings we steadily began to develop possible designs through brainstorming that were applicable to the problem Swagelok presented. Our initial designs were found to be cost heavy as well as difficult to accomplish. After using an objective tree to solidify the important aspects of the design a weighted decision matrix was formed to narrow down our design ideas. The matrix showed that, in terms of cost, time, and functionality, the self-sealing angle bracket was our most efficient design.

Throughout the following spring semester our design team continued having weekly webcam correspondence with Matthew Dixon and took occasional trips up to Swagelok in Solon, Ohio for research, testing, and manufacturing purposes. The purpose of the trips were primarily to verify and validate the proof of concept of the chosen design. The design needed to be tested to ensure that a hydraulic seal could be maintained while turning the tool handle, to ensure that the shaved hex bit allowed ample fluid flow through the check valve while in line with the flow, to ensure that the tool bit had enough length to extend through any necessary pipe adapters and then into the dual nuts within the check valves, and to ensure that the hex bit was properly designed to turn the internal nuts.

Additionally, the design team was interested in running a time study to compare adjustment times between the original procedure and the prototype design, but Swagelok felt that they did not have the necessary data to run a comparison. Instead, an operator was asked to use the prototype design and provide verbal feedback. The operator stated that he liked the new design, but he thought the shaft collar should be able to rotate a full 360 degrees around the tool shaft without interfering with the stopper clip. Additionally he requested tick marks located on the shaft that would indicate proper seating within both nuts. This feature was purposely left out of the design in order to keep the necessary amount of tools to adjust multiple check valves to a minimum. It was feared that the differing lengths of the check valves and the possibility of large initial spacing between the dual nuts could interfere with the accuracy of such markings. It was determined that making a pressure setting procedure to go along with the tool would solve the seating issue through a defined visual setup.

Conclusions

The design project proposed by Swagelok was presented with the goal of reducing the amount of time it takes to test each individual check valve. After going through the processes learned in a concepts of design course, the eight brainstormed ideas were narrowed to one. The selected final design was deemed to efficiently complete the task presented by using the processes discussed in the conceptual design. After receiving additional information regarding constraints within the system and other design factors, the selected final design needed a mild redesign to conform to the new parameters. The final redesign of the tool consisted of an assembly of the custom designed hex-bit and shaft, shaft collar, stopper clip, an off the shelf wingnut and handle, and multiple tube fittings, adapters, and seals within Swagelok’s product line. By keeping the custom designed parts easy to manufacture, Swagelok is able to keep them in-house, reducing the cost of external contracting. Keeping the use of off the shelf parts to a minimum while maximizing the use of current Swagelok products also helps keep external costs low. The design of the tool was finalized and the parts were ordered and fabricated for use in
proof of concept testing. The design team met at Swagelok and had an operator versed in the standard adjustment procedure attempt to use the designed tool. The operator gave verbal confirmation that the tool worked and offered some feedback on the tool peripherals; namely, the shaft collar and stopper clip. The design team took this feedback into consideration and made the necessary adjustments. The proof of concept design worked satisfactorily, and CAD files were created along with engineering drawings to be provided to Swagelok.
References

Appendix

Figure 1 - Angular Bracket with Cap

Figure 2 - Self-sealing Angle Bracket
Figure 3 - SEM nut Adjuster

Figure 4 - Pressure Knob
Figure 5 - Torque Wrench

Figure 6 - Force Gage
Figure 7 - Self-Automated with Star bit

Figure 8 - Compressor Sensor
Figure 9 - Objective Tree

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Figure 10 - Angular Bracket with Cap

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Figure 11 - Self-sealing Angle Bracket

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Figure 12 - SEM nut Adjuster
Figure 13 - Pressure Knob

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Figure 14 - Torque Wrench

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Figure 15 - Force Gage

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Figure 16 - Compressor Sensor
Figure 17 - Pressure Adjustment

Figure 18 - Lock Nut Adjustment
Figure 19 - Close Section View of Sealable Backend (Left side leads to Handle, Right side leads to Check Valve)

Figure 20 - 5/16" Tool
Figure 21 - 5/32" Tool

Figure 22 - Full Assembly View minus Adapters to attach Check Valve

Figure 23 - Full Section Assembly View minus Adapters