Spring 2015

Swagelok Probing Station Tester Improvement Project

Ross Crocker

*University of Akron Main Campus, rac55@zips.uakron.edu*

Please take a moment to share how this work helps you [through this survey](http://ideaexchange.uakron.edu/honors_research_projects). Your feedback will be important as we plan further development of our repository.

Follow this and additional works at: [http://ideaexchange.uakron.edu/honors_research_projects](http://ideaexchange.uakron.edu/honors_research_projects)

[🔗 Part of the Manufacturing Commons](http://ideaexchange.uakron.edu/honors_research_projects)

**Recommended Citation**


[http://ideaexchange.uakron.edu/honors_research_projects/163](http://ideaexchange.uakron.edu/honors_research_projects/163)

This Honors Research Project is brought to you for free and open access by The Dr. Gary B. and Pamela S. Williams Honors College at IdeaExchange@UAkron, the institutional repository of The University of Akron in Akron, Ohio, USA. It has been accepted for inclusion in Honors Research Projects by an authorized administrator of IdeaExchange@UAkron. For more information, please contact mjon@uakron.edu, uapress@uakron.edu.
Swagelok Probing Station Tester Improvement

Ross Crocker

Department of Mechanical Engineering

Honors Research Project

Submitted to

The Honors College

Approved:

________________________ Date ________
Honors Project Sponsor (signed)

Honors Project Sponsor (printed)

________________________ Date ________
Reader (signed)

Reader (printed)

________________________ Date ________
Reader (signed)

Reader (printed)

Accepted:

________________________ Date ________
Department Head (signed)

Department Head (printed)

________________________ Date ________
Honors Faculty Advisor (signed)

Honors Faculty Advisor (printed)

________________________ Date ________
Dean, Honors College

Reader (signed)

Reader (printed)
University of Akron College of Mechanical Engineering
Senior Design Project

Swagelok Probing Station Tester Improvement Project

Ross Crocker

Partner: Chelsea Hommel
Technical Advisor: Timothy Krick
Project Advisor: Dr. Jerry Drummond
# Table of Contents

Executive summary ........................................................................................................................................... 4
Introduction .......................................................................................................................................................... 5
Probe centering .................................................................................................................................................. 6
  Design Development .................................................................................................................................... 6
  Dimensional constraints .............................................................................................................................. 7
  Results ............................................................................................................................................................ 8
Spare Probe Holder .......................................................................................................................................... 8
  Designs .......................................................................................................................................................... 8
  Prototype and Testing ................................................................................................................................. 9
  Cost analysis ............................................................................................................................................... 10
  Results ........................................................................................................................................................ 10
Conclusion ...................................................................................................................................................... 10
Appendix ......................................................................................................................................................... 11
  Drawings..................................................................................................................................................... 11
Executive summary

A step in the inspection process for the Swagelok ends is performed using Probing Station testing. This testing process involves fitting a cylindrical probe into the open end of the fittings. Contact between the probe and the fitting causes the probe to wear. Spare probes are kept at each inspection machine to replace a probe that becomes too worn to function. These spare probes occasionally fall out of their storage location and break without ever being used in inspection. This project seeks to reduce the wear on the probes in service and reduce the number of dropped spare probes that are never used for inspection.
Introduction

Swagelok ends consist of four essential parts parts: nut, back ferrule, front ferrule, and body of the fitting. The orientation and material of each of these parts is vital to the seal provided by these ends. Swagelok is world renown for quality products and seeks to keep this reputation by thoroughly inspecting each part that bears the Swagelok name.

The Probing Station tester is a proprietary detection method used to ensure that each Swagelok end is assembled correctly. This process involves inserting a cylindrical probe into the Swagelok end. Figure 1 in the appendix shows a cross section of the probe as it would travel through the top tooling of the tester and the Swagelok end. The Swagelok end consists of the light gray nut, the red back ferrule, the orange front ferrule, and the blue body (colors are for conceptual clarity only).

The Probing Station Inspection process requires the diameter of the probe to be within 0.008 inches of the diameter of the hole in the Swagelok end. This close fit and the fact that the Swagelok end is loaded on to the probe by hand causes the part to make contact with the probe. This contact over the course of many Swagelok ends being inspected causes wear on the probe that results in false failures and equipment downtime after the probe is excessively worn.

When the probe is worn out it must be replaced. For this reason a spare probe is kept in the machine. The worn probe is replaced by the spare, a new spare is requested, and inspection continues as usual. Occasionally during normal operation or maintenance of the test machine, the spare probe will be dislodged from its storage location and fall to the floor. This fall can break the probe before it is ever used for inspection.

There are two goals for this project. The first is to design a method to eliminate contact between the Swagelok end and the probe during inspection in order to increase the useful life of the probes. The second is to design a holder for the spare probe that eliminates dropping of the spares.

The designs for this project focused on the Probing Station test equipment for the 400 series Swagelok ends. If the designs proved successful they would be implemented across all series of Swagelok ends.
**Probe centering**

In order to prevent the Swagelok end from coming into contact with the probe during loading, the part must be centered over the probe. The criteria for a design that would be put into action were selected to be safety, effectiveness, size, and cost. Safety included but was not limited to ensuring that anyone operating the inspection machine would not be injured and that maintenance personnel were able to work on the machine without special tools. Effectiveness was used to describe the extent to which the design was able to prevent contact between the Swagelok end and the probe. The size criteria limited the design to fit within the envelope of the present Probing Station Test Machines. The cost of the design had to be less than five thousand dollars per machine. This cost included materials and maintenance, but not design costs.

**Design Development**

Design number one involved modifying the tooling on which the nut rests during inspection. The tooling has a hole through which the probe would travel. The modification would be a ridge around this hole that would engage the chamfer on the nut of the Swagelok end. This would, in theory, center the Swagelok end over the hole in the tooling while the probe was in a down position, preventing contact between the part and the probe. A sketch of this design can be seen in figure 2.

Design 1 had the advantage of fitting in the required space and it would not introduce any safety issues. It would however cost a significant amount to purchase the new part of the tooling for each machine and have them installed. Ultimately this design was not chosen because the chamfer on the nut is not held to a tight tolerance in size or concentricity, meaning that the contact between the ridge on the tooling and the chamfer on the Swagelok end would not reliably align the Swagelok end over the probe.

Design number two employed a gauge pin to center the part. The gauge pin would be on a rail and actuator system in parallel with the Probing Station probe. The gauge pin would be in the up position when the part was loaded then would cycle down. Both the gauge pin and the Probing Station probe would then move horizontally until the probe was under the part at which point the probe would travel up in to the part to perform the inspection.

Design 2 would involve loading the Swagelok end in the current fashion, which would prevent new safety concerns; and the gauge pin would be less costly to replace than the Probing Station probe. The design would require design of the lower tooling of the machines and ultimately would not fit within the current machine size. There would also be great cost in assuring that the Probing Station probe was perfectly aligned with the axis of the Swagelok end after it was moved into place. This design was not chosen based on the cost of the precision mechanisms required to realize it, and the high chance that the probe would still make contact with the Swagelok end.

Design number three made use of self-centering grippers and a pneumatic actuator to hold the Swagelok end over centered over the probe. The actuator would be mounted to the top surface of the machine with the grippers moving along the plane of the surface. The
Swagelok end would be placed in the tooling with the probe in the down position to prevent contact. The actuator would then close the grippers around the machined surface of the body of the Swagelok end. Figure 3 shows a sketch of the grippers. Figure 4 shows the surface that they would close upon.

Design 3 would be the most repeatable of the designs and most likely to be able to perform the centering task. The actuator, grippers, and installation would be excessively costly. Safety devices would be required to eliminate pinching risks. Keeping the machine in calibration would require extreme care. Despite these concerns, the main factor preventing implementation was the uncertainty of the axial alignment between the hole in the Swagelok end and the probe provided by the thin grippers on the body of the Swagelok end.

**Dimensional constraints**

The parts that make up the 400 series Swagelok end have a through hole with dimensions in the range of 0.253-0.255 inches. The Probing Station probe is a cylinder with dimensions in the range of 0.247-0.250 inches. This means that in the worst case the tolerance between the diameter of the hole and the diameter of the probe is only 0.003 inches. Achieving alignment this accurate would require precision mounting of any system used to center the Swagelok end over the probe.

For designs one and three, the surfaces that would be used for alignment had tolerances up to 0.010 inches in the diameter and up to 0.005 inches in position. This means that from part to part the centering design would not be guaranteed to work.

Not only would the diameters of the probe and the hole need to be aligned but the axes would need to be nearly perfectly aligned as well. Based on the geometric calculations that can be seen in figure 5, if the axis of the hole in the Swagelok end was out of angular alignment by only 0.00005 degrees the probe would make contact with the Swagelok end during its vertical cycle.

The tooling in the machine does constrain the probe axially. Figure 6 shows a cross section of the machine. The tooling has holes with diameters $D_1$ and $D_2$, and thickness's $T_1$ and $T_2$ which are separated by distance $d$. Analyzing the possible movement of the probe within these constraints shows that it can be out of vertical alignment by up to 0.0011 degrees, or 22 times that of the allowable misalignment of the axes of the Swagelok end and the probe.
Results
With these dimensional constraints and the time constraint of the project we were not able to produce a working prototype. We did however obtain some useful information and considerations for future work on this problem.

If the tooling is kept the same size, the probe would have to be sized down to 0.192 inch maximum diameter to allow for the probe to travel through the Swagelok end without making contact.

Other possibilities that time did not permit pursuing, but that would be valuable to investigate are: modifying probe dimensions, increasing the shielding on the tip of the probe, and removing the shielding from the probe to increase clearance.

Spare Probe Holder
Because the probing station probes can wear quickly, a spare probe is kept in each machine. This enables quick replacement of a damaged probe to minimize machine downtime. Currently the spare probe is held in a broom holder. An example of this probe can be seen in figure 7. This holder is easy to use but the probe frequently is dislodged from the holder and falls to the ground. Some of these falls are fatal to the probe. The probe being held for emergency change over is then useless. In the event of a change there may not be another probe readily available. The goal of this project is to create a holder that will not allow dropped probes. The new holder must satisfy space, ease of use and maintenance, cost, and availability constraints. The space constraint is that the holder fit in the machine enclosure without interfering with the machine operation. The holder must be easy to insert and remove the probe. Spare parts must be available in reasonable time. The cost must not be significantly greater than the current holder. The parts should be available from common suppliers without modification.

Designs
Design number one involved adding a block with a hole in it to the existing clip. The probe would be inserted through the hole then held in place with the clip. This block and clip design can be seen in the sketch in Figure 8.

Design 1 would be more secure than the original. It would be difficult to find the block with the right size hole in it without getting it custom made. It would also take up more space in the machine and be more difficult to use. This design was not selected for the task.

Design number two utilized the part of the tooling in the machine that secures the probe while in use. Mounting a second of these blocks in place of the broom holder would provide and extremely secure spare probe storage. The probe would be clamped into place using a threaded fastener to tighten the two sides of the block together. A sketch of the tooling block can be seen in Figure 9.
Design 2 would hold the spare probe extremely securely and the block is already registered in the Swagelok system. The block is more precise than necessary for holding the spare probe, which would cause it to cost more. The tight fit between the block and the probe and the need for a threaded fastener would make loading and unloading the probe time consuming. Additionally fitting the block into the existing machine enclosure would be troublesome. This design was not selected for the task.

Design number three consisted of fastening a hook and loop strap to the side of the enclosure. The probe would then be strapped in securely. This hook and loop strap can be seen in figure 10.

Design 3 would be the most adjustable and smallest space requirement. It also would be cost effective and made from off-the-shelf parts. The reason this design is not good is that it would not necessarily be used correctly. If the strap was not tight the probe would not be held at all. It is very likely that the probe would slip out of the strap due to vibrations of the machine. This design was not selected for the task.

Design number four used design ideas from both designs 1 and 2. An off-the-shelf block with a hole, like design number 1, in it was found in a Swagelok tube support. This block comes in two halves and can be tightened around the probe. Instead of using a threaded fastener to do the tightening, springs were employed between the mounting bolt heads and the tube support to press the two halves together. The force of the springs was calculated to be sufficient to close the clamps but low enough that an operator could pull the halves apart to insert or remove the probe. To provide a secure mount for the tube support hex nuts were pressed into the counter bored holes on the half of the tube support that was nearest the wall of the enclosure. The bolts were then inserted through a stainless steel plate, the springs, both halves of the tube support and threaded through the nut. Another nut is used on the outside of the cover to hold the system in place. The parts of this holder can be seen in an exploded view in figure 11.

Design 4 used all off the shelf parts, fit the space requirement, cost only a few cents more than the original holder, and held the probe securely. This design was selected for the task.

**Prototype and Testing**

Using design 4, a prototype was assembled and installed on a machine in the factory setting. The first version was made entirely from parts acquired from within the plant, so the cost was negligible. Initially the springs were installed on the side closest to the cover and the bolt heads were pressed into the counter bored holes. This caused the holder to have freedom to move in all directions. Figure 12 shows a picture of the installed first prototype. Based on observations of the prototype the springs were changed to ones with a lower spring constant to make the opening of the hole slightly easier while still maintaining a secure hold on the probe while in storage.

During the test installation of the prototype, a group of three operators were surveyed for their opinion on the new design and their ideas for improvements. The operators liked the security and did not mind the slightly longer time it took to insert and remove the probe.
One suggestion that was made was to move the springs from the bolt head side to the cover wall side. This suggestion was tested and proven to make the holder more stable and easier to operate. Adding a handle was also suggested but was not possible to implement before the end of the project.

Cost analysis
The parts required to change the spare probe holders on the 37 Probing Station test machines in the plant will cost $75. The labor cost of installing these parts will be approximately $925. This means that the total cost of changing to the new spare probe holder is about $1000. If two spare probes are preserved for use in testing this new holder will save the company $600 per year. Data on the number of dropped spare probes is insufficient but there are likely more than two dropped probes per year. This means that implementing this holder as standard is a good financial decision.

Results
Once the design was finalized, instructions for the installation of the new holder were written. The maintenance department was contacted to plan time for the installation. The parts for the holder were ordered and each machine should have a new spare probe holder as soon as the maintenance department has time to complete the installations.

Conclusion
The Probing Station test probes become worn with regular use in the inspection of Swagelok ends. The goals of this project were to increase the life of the probes used in inspection and prevent the spare probes from becoming damaged before they were needed.

The devices for preventing the Swagelok ends from coming into contact with the Probing Station probe during inspection were not practical to implement within the constraints of the project. Progress was made in the definition of the problem and some potential solutions. A smaller probe, harder shielding, or reducing the size of the probe by removing the shielding would all be viable solutions to the problem and merit further investigation.

The holder for the spare probe was successfully designed and will be implemented in the near future. The savings realized from not wasting the spare probes will be more than enough to cover the implementation of the new plan. This change makes financial sense.

The improvements that were made through this project will certainly save The Swagelok Company money, but the progress made in the development has potential to save far more. The team would like to thank both Swagelok and The University of Akron for the opportunity to work on such a rewarding project.
Appendix

Drawings

Figure 1. Swagelok end in Probing Station Test Tooling.
Figure 2. Probe centering design 1.

Figure 3. Probe Centering design 3
Figure 4. Probe centering design 3 grip location.

Figure 5. Probe centering geometry of the Swagelok end.

Travels upward about 0.5
Side clearance of 0.0015 = 0.00H
So calculate the angle between

\[ \theta = \sin \left( \frac{0.0015}{0.5} \right) \]

\[ \theta = 0.0000524^\circ \]
Figure 6. Probe centering geometry of the machine tooling.

Figure 7. Spare probe holder current design.
Figure 8. Spare probe holder design 1.

Figure 9. Spare probe holder design 2.
Figure 10. Spare probe holder design 3.

Figure 11. Spare probe holder design 4 layout.

Figure 12. Spare probe holder design 4 prototype installed.