

# 5160 Assembly Cycle Time Improvement

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by

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## **Problem Statement**

Cycle time has been a focus point on our 5160-damper line for the past 3 months. As the demand for 5160 dampers has increased, more attention has been brought to the assembly process for this product lineup. With actual cycle times being consistently over the preset target times, the production of these parts is falling short of target. I plan to focus on this issue to decrease the time it takes to produce 5160 dampers.

## **Research**

### **Background of the Problem**

Over the past couple of years in Bilstein Aftermarket, more tasks have been added to the list of production parts. As more 5160 jobs are added to the catalog, the demand for these dampers has increased over the past year. According to SAP, these dampers are targeted to be produced in 62 seconds where the actual average is closer to 85 seconds and above (1). 5160s are taking longer to produce than initially predicted. These dampers can take up to 45 seconds over the predicted cycle time to manufacture depending on the shift and part number being run (2). This is causing backups and a staggering amount of 'waiting around' time for the operators in the area, expect for the operator that works the hose assembly machine. A breakdown of the part can be seen in appendix 3.A.

There are multiple parties that are impacted by the problem of increased 5160 volume and long run times. First being production. The production floor is divided between three sections for ideal material flow to build our dampers. A damper is built with a few basic components. A tube machined in our tube department, a piston rod with corresponding valving to

the part number and is assembled with pressurized gas and oil in our mains department. Then finalized with a bushing, label, and boxed in our finals department. With the back up being in mains, finals can finalize parts faster than what mains can build, causing a lack of work for other production areas. This leaves employees doing busy work instead of producing parts, which is a loss for the company. Scheduling is also affected due to backloging parts. These parties then turn to the engineering team to question why times are not being met and what needs to be done to increase productivity.

With the issue of high cycle time, the operators spend nearly half the time waiting for the hose assembly step of the production line. The operation works as follows. A gas reservoir is filled to a pressure and a cap is pressed on. This is then assembled to the main body tube via a braided hose. The hose is torqued on to a specific spec and is passed to assembly. The hose assembly table backs up the line every time 5160 parts are run. The average cycle for a 5160 to go through hose assembly is 90 seconds while the average gas/oil cycle is 37 seconds resulting in a 53 second operator wait time.

### **Applicable Standards**

Standards for the machine include ergonomic heights and dimensions, torquer tolerances, Loctite tolerances, and overall tooling standards for dimensions, materials, and tolerances. Tolerancing uses ISO 14405-1 standards. Safety standards include the elimination of pinch points. If pneumatic, servo driven, or hydraulic clamps or components are used that could be a pinch point, two hand touch buttons are to be put in place to avoid injury.

## State of the Art

The process of hose assemblies has been improved over the years as new machines were implemented and new technology was added. The current state of the machine is an aluminum table with three fixture stations. Each fixture has a purpose depending on what part number is being built. The parts are loaded into the fixture and clamped shut by hand and then locked by pneumatics via button press. Once the parts are fixed, the operator will apply Loctite to the hoses and any other threaded fitting. These hoses and fittings are torqued on by a torque gun and will automatically stop the torque gun when the value is reached. Finally, when the PLC sees that all operations have been complete, the finalized part will be released and move on to the next station.

The machine has an overabundance of steps for a single operator to complete efficiently. The operator is responsible for loading the tubes, applying Loctite, adding crush washers, adding an adapter spacer, hand tightening and torquing the hose assembly, and unloading and handing off the finished assembly. The problem with this is that this takes a long time. The target time defined by SAP for the process is only 62 seconds (1). After conducting cycle times studies, the results show that the average time is 90 seconds, almost 30 seconds above the predicted time. The problem with this is that all our targets are set from the set target time. This causes the calculated production targets to naturally be off, even when the cell is working at peak efficiency. This gap in time shows we lose out on about one to four thousand parts per month depending on run time of 5160s and about an \$80,000 value per thousand parts (3). The problems are currently being addressed by placing the engineering team in production to document what problems main assembly production faces during the day and create projects to make improves on the process. Over the past 6 months, new Loctite fixturing was introduced to

be more consistent and cleaner, as well as new tube fixturing's were implemented to not scratch parts and be more operator friendly. These small improvements were meant to decrease the cause of a problem. Recently, more time has been spent reacting to issues in production.

## **End User**

The improvements to the process will benefit Bilstein Aftermarket and the entire production team. The ability to produce more parts in a shorter amount of time will allow more jobs to be added monthly and have a higher monthly output of 5160 dampers. The company will be able to profit from the higher output and put the investment back into the line to make further improvements.

## **Summary of Research**

After conducting research on the topic, improvements need to be made to make the operation more efficient. These improvements include adding additional steps to the previous operation to make the hose assembly operation more balanced. This can include adding Loctite stations, tube fixturing, and part storage. If the process can output parts closer to the set target time, more jobs can be added and in turn, more parts can be made. This output should be able to be seen monthly as output and production numbers are documented. Once the improvements have been implemented, data will be compared before and after the changes to show the success of the investment. The target for this project will be to decrease the current time by 25 seconds per on average per part and show a smaller part deficit due to the time saved.

# Quality Function Deployment

## Customer Features

1. The station needs to have one torque gun.
2. The station needs to have at least one Loctite dispenser.
3. Hoses need to be stored on the table.
4. Crush washers need to be stored on the table.
5. Touch sensors need to be used to signal important steps and safety features.
6. A clamp station for the reservoir to sit horizontally.
7. A clamp station for the reservoir to sit vertically.
8. Spacers need to be stored on the table.

## Engineering Characteristics

1. Torquer must have a tolerance of at most  $+0.5$ ,  $-0.01$ .
2. Station must have at least one touch sensor
3. Station must have a working height of 90 – 120 cm.
4. Station must be less than 1 meter by one meter in area.
5. Tabletop storage must hold at least one bundle of hoses.
6. Loctite amount must be controlled to three drops per application.
7. Fixture system must be able to withstand at least 30 Nm of torque.
8. Torquer must be able to change directions and store data.



**Product Objectives:**

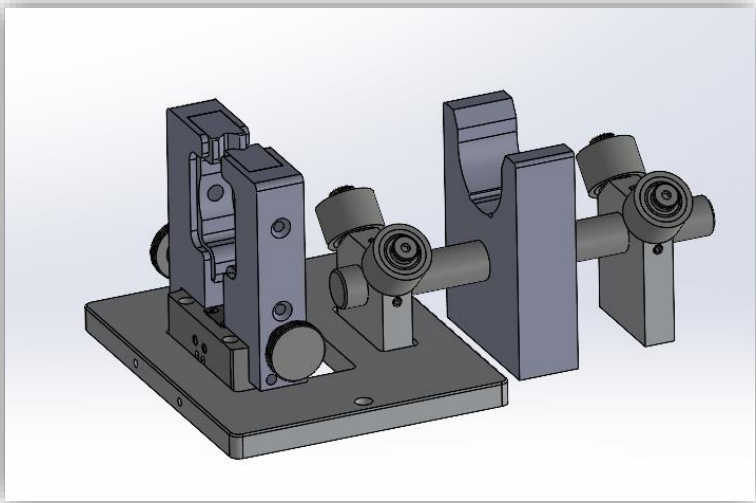
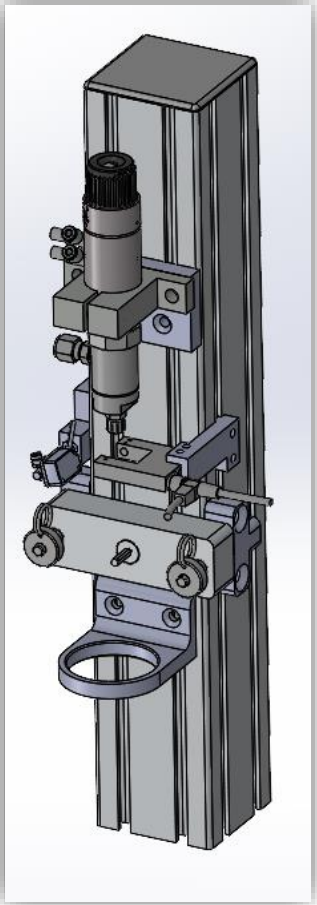
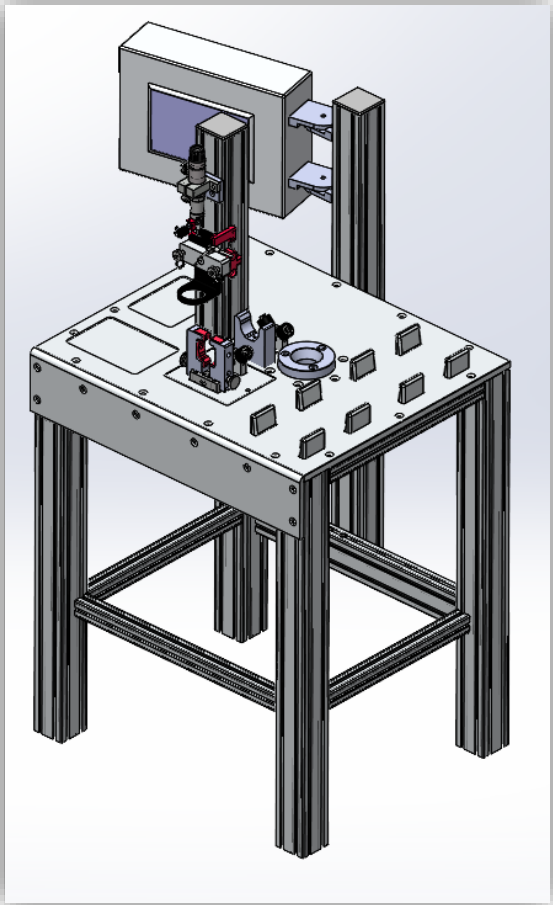
1. Meet target cycle time of 62.02 seconds.
2. Split up the current work evenly up among the three current station.
3. Balance the build time of each step in the 5160 processes.
4. Build a more consistent workflow though the work cell.
5. Allow for more 5160 parts to be built monthly as demand increases.

**Team Members and Responsibilities:**

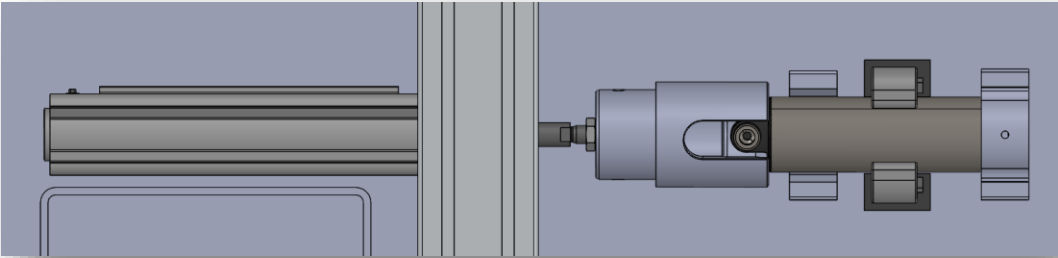
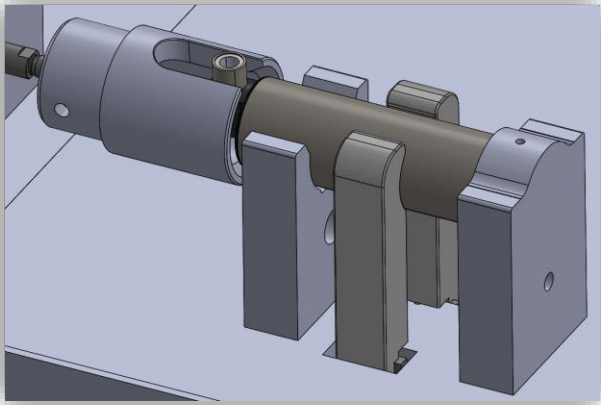
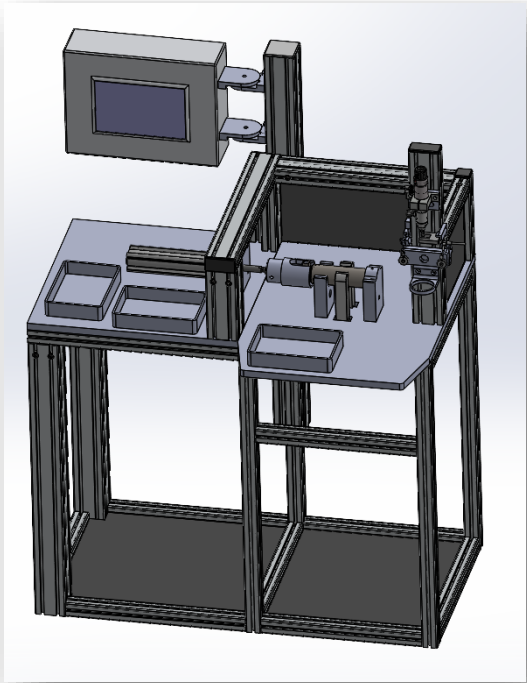
I am working independently on this project. My responsibilities will include designing and testing the 5160-table addition. Testing will include monitoring monthly 5160 output and the average logged cycle times to compare to the current process.

**Design**

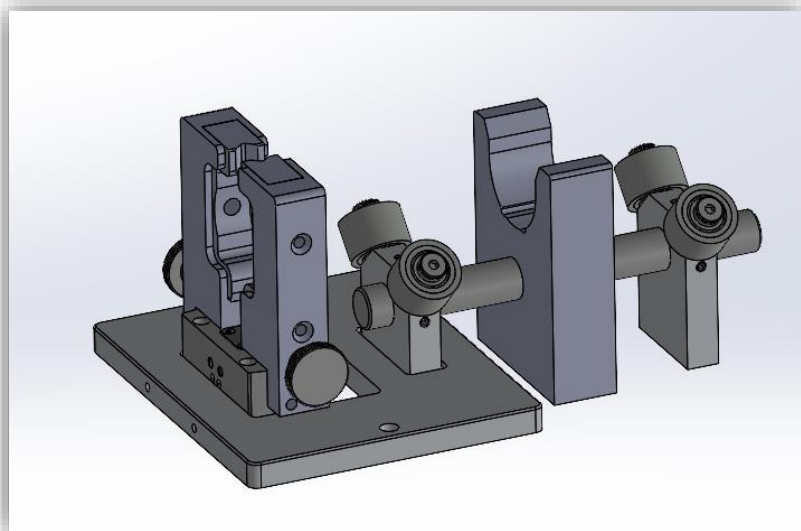
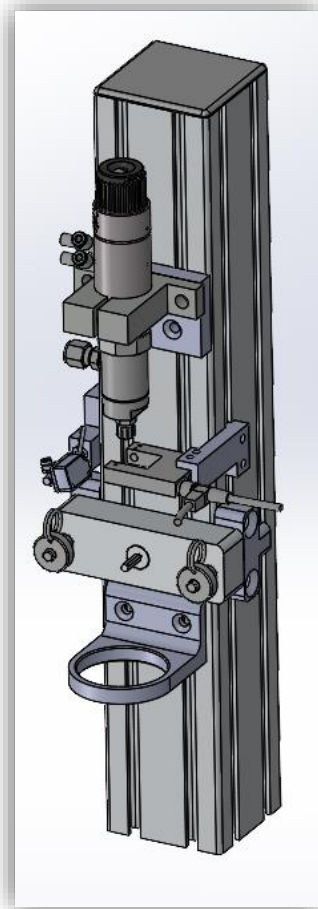
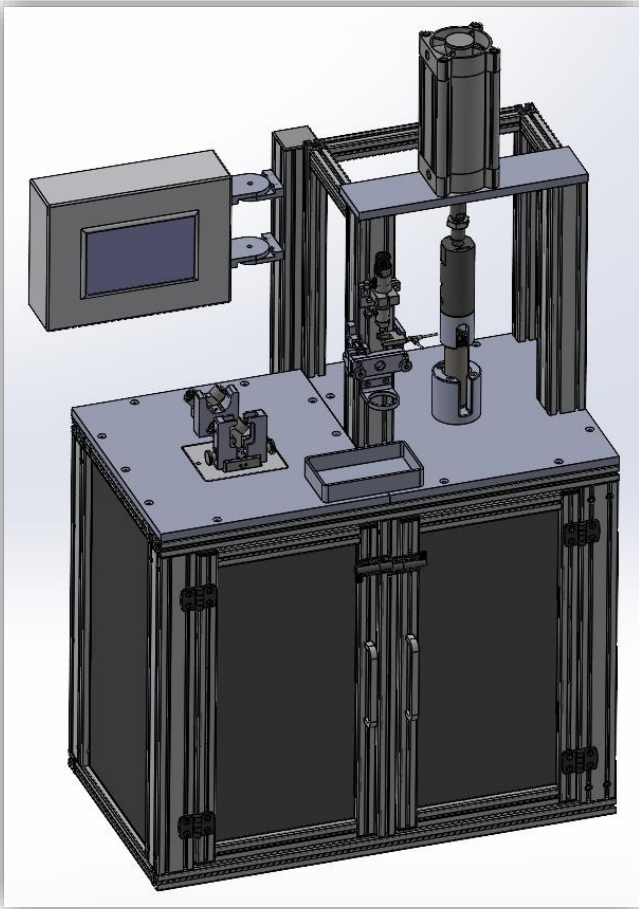
**Concept 1:**



**Concept 2:**



**Concept 3:**



## **Design Analysis:**

### **Concept 1:**

Concept 1 provides a familiar design to the operators. The tabletop follows the design that is currently on the line but condensed to one station. This station can take on one of the three torquing operations that is currently being ran by the hose table. With this design, two different torques can be easily transferred to speed up the operation and remove a torquing process from the current table. Lastly, the Loctite station is also a similar design to what is already seen and used by the operators. It can detect part presence and control the amount of Loctite applied to the part.

The upside to this concept is the simple layout that the operators are already familiar with. The PLC writing would be like the current process as well as many of the components. The downside to this concept is the overall cost. This concept brings a new machine to the line which would need to be added into the process. With floor space being tight, this concept did not seem to be a feasible solution long term to decrease cycle time.

### **Concept 2:**

Concept 2 has been brought into existence by taking the process of an existing machine and rotation the press operation 90 degrees and adding a torquer with a retractable arm. The current press operation is a single pneumatic cylinder that presses on a small dust ring to protect the edges of the cap that is installed on the reservoir. With rotating the press and adding the torque, we were able to remove an assembly step and combine it with the torquing process. The Loctite station on this concept is also like that of concept 1 and the current design.

The upside to this concept is that it uses components from an existing machine. The PLC would still be similar but would need updated to read the addition of the press operation. The

contrasting side is that this concept would also have a higher cost with more pneumatics and new PLC needing to be added. There will need to be a significant number of upgrades to the current machine to make this work. The biggest factor of concern is that this concept is only dedicated to decreased one type of damper reservoir.

### **Concept 3:**

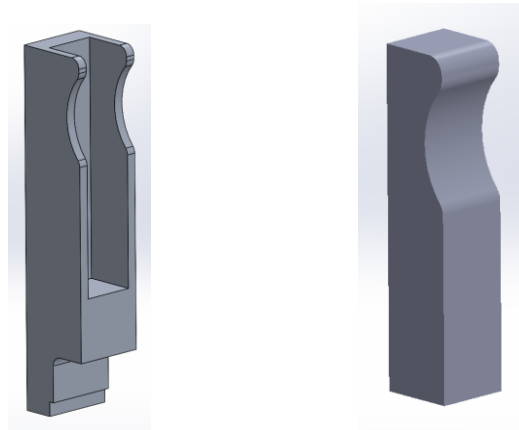
Concept 3 provides a balance between using components off the current pneumatic press and using a similar tube fixturing from our current table. Using this allows the operators to feel comfortable using the machine upon launch as well as being able to use similar coding. With this concept, we can use the same company that coded our current machines to build and test this concept. A new torquer and torquer arm would be added to the station as mentioned in concept 1 and 2. Lastly, this concept allows the potential to add change out tooling to torque more parts in different orientations that either of the above concepts.

The upside to the concept is the ability to torque more than one part. The tooling would be able to be changed out to torque vertically oriented tubes which opens more part numbers to decrease cycle time to. With the concept adding in existing components, it provides a lower cost compared to the other two concepts as well as being able to use similar PLC.

### **Loading Conditions:**

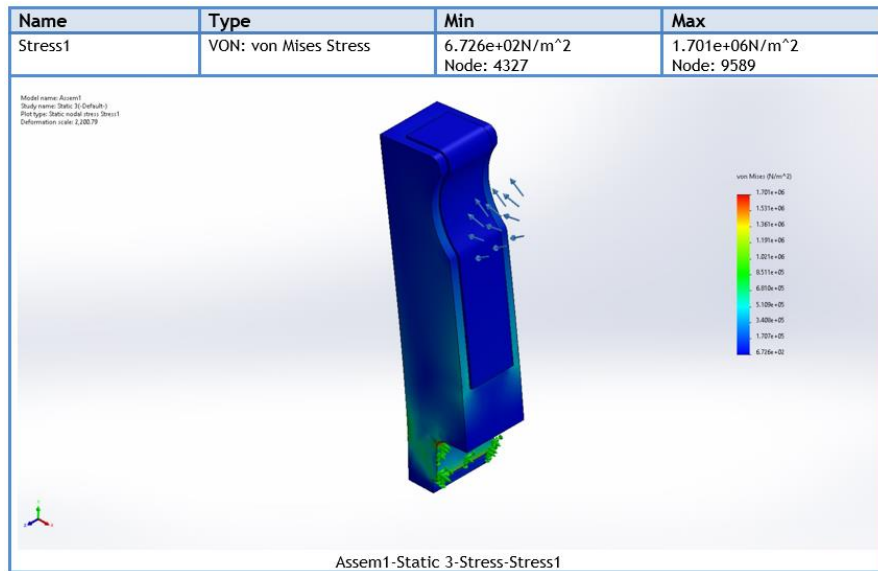
Loading conditions for concept 3 were related to the grippers and the lower tooling that is to be pressed down on while installing the dust ring. The FEA results are as follows.

**Grippers:** Aluminum casing pictured on the left, Delrin insert pictured on the right.

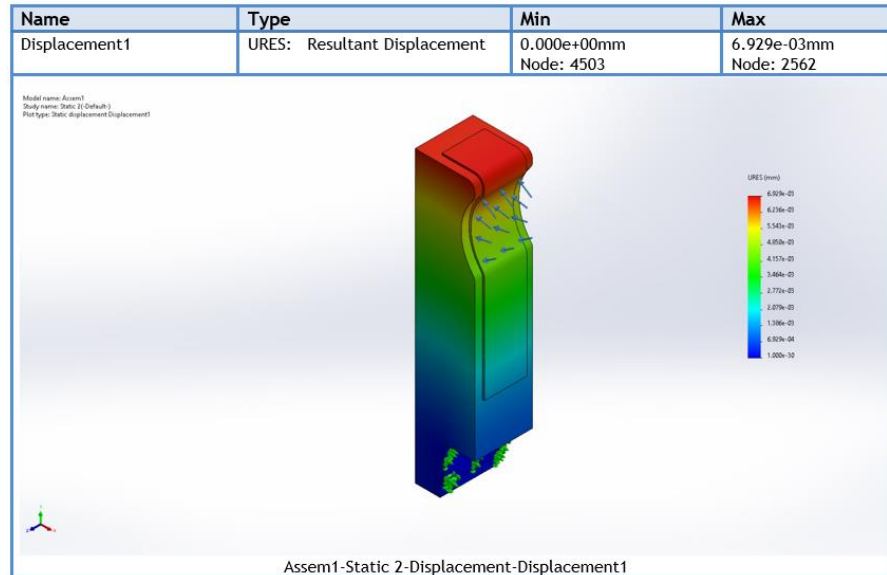


**Stresses:**

The stress is seen when the torque is applied to the tube and the tube will have a rotational force when torqued to spec. When the force is exerted, the grippers see a max von mises stress of 1.7 MPA (pictured in figure 1 below). The yield for 6063-T1 aluminum casing is 90 MPA and the Derlin insert has a yield of 63 MPA. The max displacement (pictured in figure 2 below) is  $6.929 \times 10^{-3}$  mm and a max strain of  $1.869 \times 10^{-5}$ .

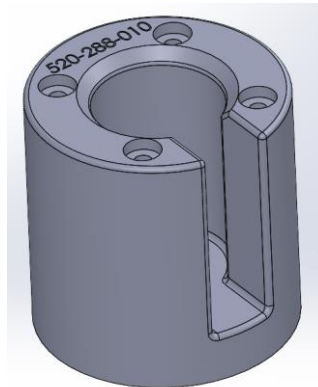


**Figure 1.**



**Figure 2.**

**Tube Containment:** This piece holds the tube when the dust ring is pressed on. 10kN is exerted when the press is activated.



**Stresses:**

The stress is seen when the pneumatic cylinder is actuated, and the dust ring is pressed on. A max of 10kN of force is exerted from the cylinder. A max von mises stress is seen of 4.2 MPA (figure 1 below) with a Delrin material yield of 63 MPA. The max displacement seen is  $2.472 \times 10^{-3}$  mm (Figure 2 below) and a max stain of  $1.165 \times 10^{-3}$  mm.

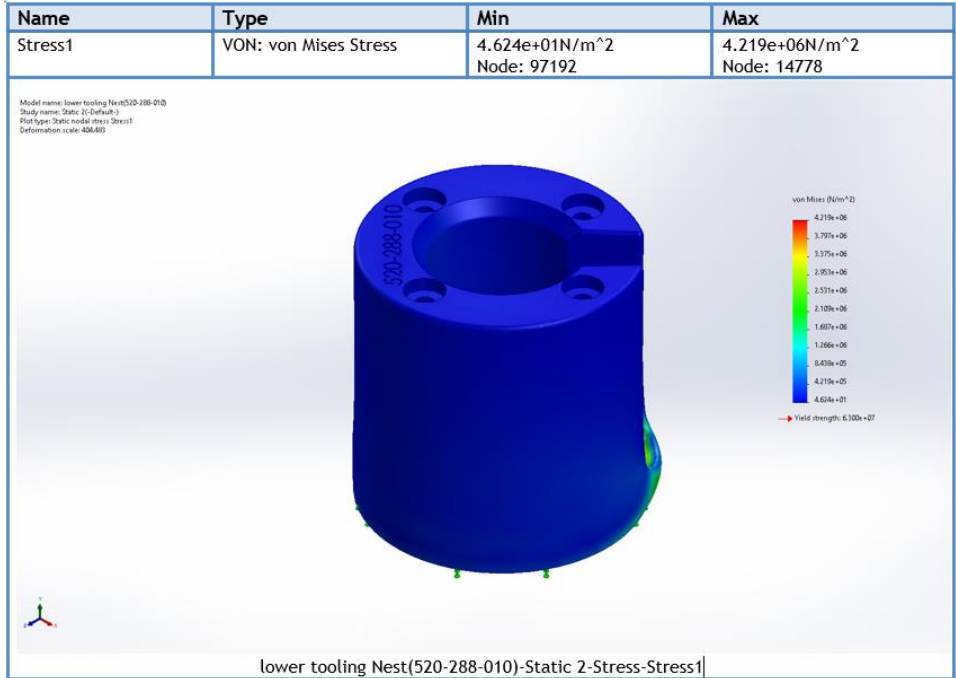


Figure 1.)

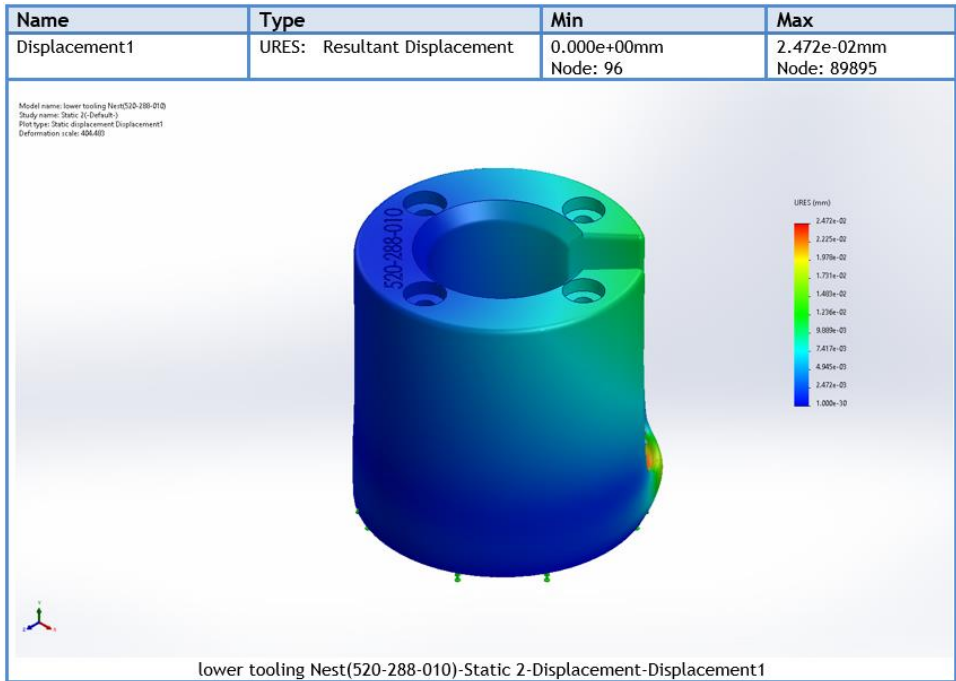


Figure 2.)

**Bill of Materials:**

Build Of Materials		
Item	Source	Quantity
Framing	Monarch	1
Custom Parts	Hubs	1
Parallel Grippers	Festo	1
Press Cylinder	Festo	1
Atlas Torquer	Atlas Copco	1
Atlas Arm	Atlas Copco	1
Loctite Module	Henkel	1
Standard Parts	McMaster	1
Rollers	Misumi	5
Touch Sensors	Allen Bradley	2
Air Shut off Valve	Festo	1
Air Shut off Valve	Festo	1
Air Regulator	Festo	1
Prox Sensor	Festo	2
Thru Beam Sensor	Balluff	1
Fixture Sensor	Pepperl Fuchs	1

# **Testing and Proof of Design**

## **Testing Methods:**

With the extent of this project, there was heavy testing done to ensure that the project had maximum flow and maximum time saving. The first test was to get a baseline time from our current hose table ran by engineering and operators. In this test, cycle time was taken during production. From this study, there was one test that we could try that could eliminate a torquing process. Another testing method was to add and test the option to heavily automate this process. Testing automation was the bulk end of the testing with the number of options available to apply to this station. There is little to no automation on the current build process for these assemblies.

## **Double Torque Study:**

This study was the first test moving forward with the project. As pictured below, we wanted to challenge if both the fitting and adapter could be torqued together at the same time. For reference, there are crush washers in between each fitting. For example, a washer would be placed between the tube cap and the adapter, and one would be placed between the adapter and the hose fitting. This test was run by engineering on a one-off program. If the test was to come out successfully, the torque station could be focused on torquing a hose end on every part. This would eliminate more work on the hose table or eliminate an extra torque process all together.

## **Automation Testing:**

With the project being a new production machine, we wanted to challenge the technology we can add to it rather than sticking with manual operations. This testing was dedicated to how we could automate the torque, automate tube fixturing, automate Loctite, IV/IX camera detection, loading/unloading parameters, failure modes, and rework nests. The important part

about testing the torque, we needed to ensure that the torquer did not crash into the part.

Locations were very rigid so the hex on the torquer met with the fitting on the part every time.

Pneumatic slides were tested using aluminum extrusion for mounting and Festo Pneumatics. The controls team that is involved are familiar with coding this into the PLC and have some machines that use similar approaches. Fixtures needed to be updated from the original concept to be more rigid and allow zero movement once the part is clamped. Change over tooling also needed developed to show that tubes of other orientations can be ran as well. The success of this test could open the door to automate more than just one torque.

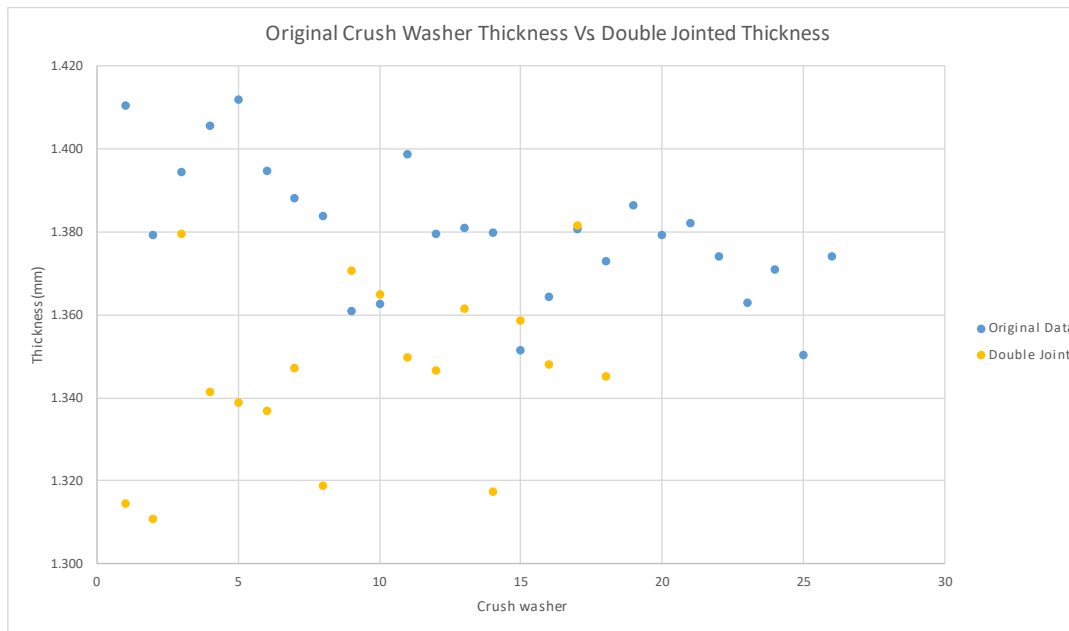
Evaluating IX/IV camera detection is in attempt to detect proper components and their presence in the build. These cameras are heavily used as of recent in new machines in the plant to detect specific tolerances. The idea is to detect the presence of a crush washer, correct hoses, and orientation, and to verify that Loctite was added to the part.

## **Results:**

### **Double Torque Results:**

The results for torquing both fittings on at the same time is inconclusive. The recorded parameters that were used to detect a successful torque was a passed part on the torque module (all parts measured passed both torque and angle specs) and the deformation of the crush washers. The graph below shows the crush washer deformation. The blue dots represent single torqued parts and the deformation, and the yellow dots represent deformation from double torqued parts. Some of the points in yellow were not deformed as high but still met the deformation requirement. The recorded data supports the idea of stacking torques. After analyzing the data, we reached out to Atlas Copco (torquer supplier) to get their input before moving on with this idea. After discussing the topic, Atlas was not confident that their module and torquer could

sustainable torque more than one fitting at a time. With an increased risk of failure and with the possibility of sending our customers leaking fitting, the idea was deemed too uncertain to implement into the process.



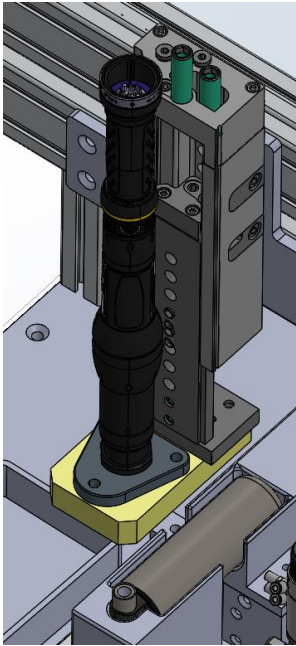
### **Automation Testing Results:**

Automation testing was successful. With the torque being able to be controlled with automation as well as having proper fixtures to clamp the parts into place for horizontally orientated parts, we are able expand this to any part that is orientated horizontally. With that said, our controls and engineering team wanted to investigate expanding this technology to the other torquing operation seen in hose assembly. This now involves three more torques, three more hose types, and two more tube orientations. Regardless of the parts, the torque can be in the same location for each part with the lower tooling designed with change overs in mind. The lower plate can be removed, and a new fixture installed. This still needs further work to account of the amount of tube lengths ran and new productions coming. The potential savings for automation

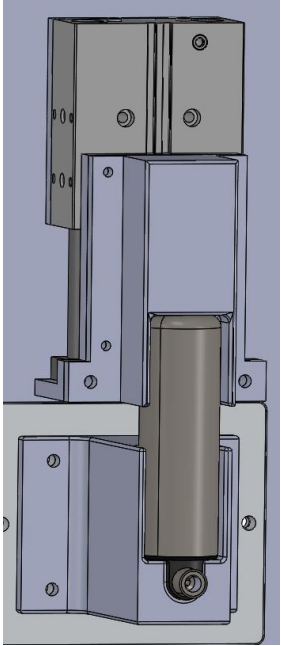
exponentially increase from the initial cost savings in the project. Cycle time could potentially be 10 seconds under target time compared to the initial predicted time of 5 seconds over target.

IV/IX testing was also successful. Crush washer presence can be detected before proceeding to build. This can eliminate parts leaving our facility without crush washers as there is no PLC check currently in place. This is not an issue that has been dealt with, but it is an issue that we are able to prevent from happening. The IV/IX camera testing has not been as extensive as there are possible part changes coming soon. This involves the possibility of the crush washer being eliminated completely and replaced with an O-ring. With this being a possibility, we wanted to see where the meeting ends up before proceeding and further challenging our camera detection.

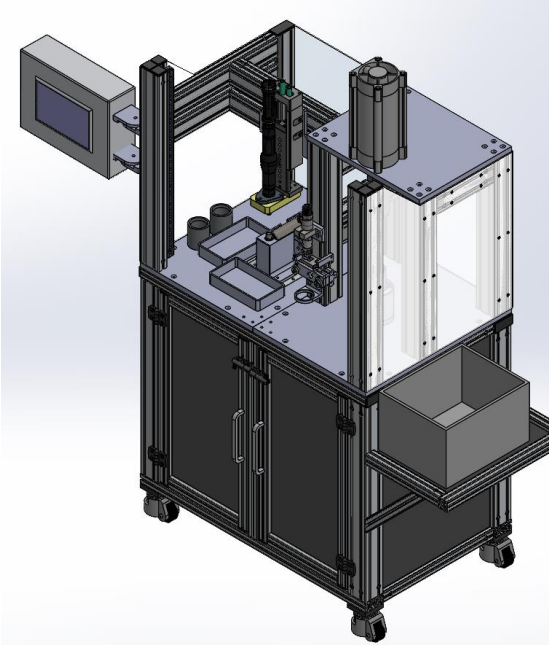
The design changes to include automation are shown below. Figure 1 shows torquer mounting and pneumatic slide, Figure 2 shows new tube clamping, Figure 3 is a full machine overview to include an enclosure and light curtains.



**Figure 1**



**Figure 2**



**Figure 3**

# **Fabrication and Assembly**

## **Fabrication Process:**

Fabrication for this project has been planned but delayed as advancements have been made in terms of automation and the product that is being worked with. Fabrication plans go as followed. Once all automation has been concluded and finalized, we need to wait to see the current product we are working with the make changes before setting up. Once this has been complete, framing will be purchased and assembled as this is the bones of the machine. Framing must consider the overall size of the machine, floor space taken up, and process flow plans. Once framing has been implemented, tabletops, pneumatic components (Festo), custom and stand parts (hubs, Misumi, McMaster, etc.) and torquers (Atlas Copco) can be ordered. This is to be shipped while the frame is being constructed. With the frame being aluminum extrusion, we have full control of how these components are placed. After assembly has been finished, the project will be handed off to our in-house controls team. They are responsible for electrical and pneumatic plumbing and schematics (quoting received), all PLC programming and start up support.

All custom parts were designed in house. Parts were needed to be designed for many contrasting functions such as adapting the torquer to the extrusion, holding sensors in place, adapting the Loctite dispenser to extrusion, and the lower tube fixtures. The tooling designs are as follows: All pictures are shown in the Appendices section, all parts described are colored in gold. The torquer required two plates to attach the torquer to the pneumatic slide and adapter the pneumatic slide to the extrusion. The design is shown in appendices section 4.A. The sensors to be held in place are to detect the Loctite drips and part presence. Combined in this are the parts to adapt the Loctite dispenser onto the extrusion. The parts for this are in section 4.B. Tube fixtures were designed as well to lock the parts into place before torquing. These parts have been

designed to be changed over for other tube orientations and different tube lengths. These parts are in gold in section 4.C. Lastly, parts have been designed to press on the dust ring onto the reservoir before moving on to torquing. This is a nylon piece so the part or the dust ring does not get damaged. The lower tool is a Delrin piece to hold the tube in place and not get scratched during insertion and removal. These parts are shown in section 4.D.

With using an in-house controls team, I can work closely with them to ensure everything is on track and going to plan. Another advantage is that plans can be adjusted accordingly based on project priorities since they are used plant wide. OE Department projects are typically viewed as a higher priority and this project will get worked on with a 5-week plan. This plan includes 2 weeks electrical and pneumatic plumbing, 2 weeks PLC programming, 1 week to troubleshoot.

#### **Assembly Methods:**

Assembly for this project is to be done in house by myself and our controls team. Assembly will take place as parts arrive with the framework first and all components as they follow. Assembly can be expanded depending on the final scale of the machine. Since automation is planning to be added to the machine, all parties involved want to grow the project to take on more than just adapter torquing. This can involve adding one or two more additional stations to torque parts in line. Assembly will be done by myself and our controls team regardless of the size of the station.

# Project Management

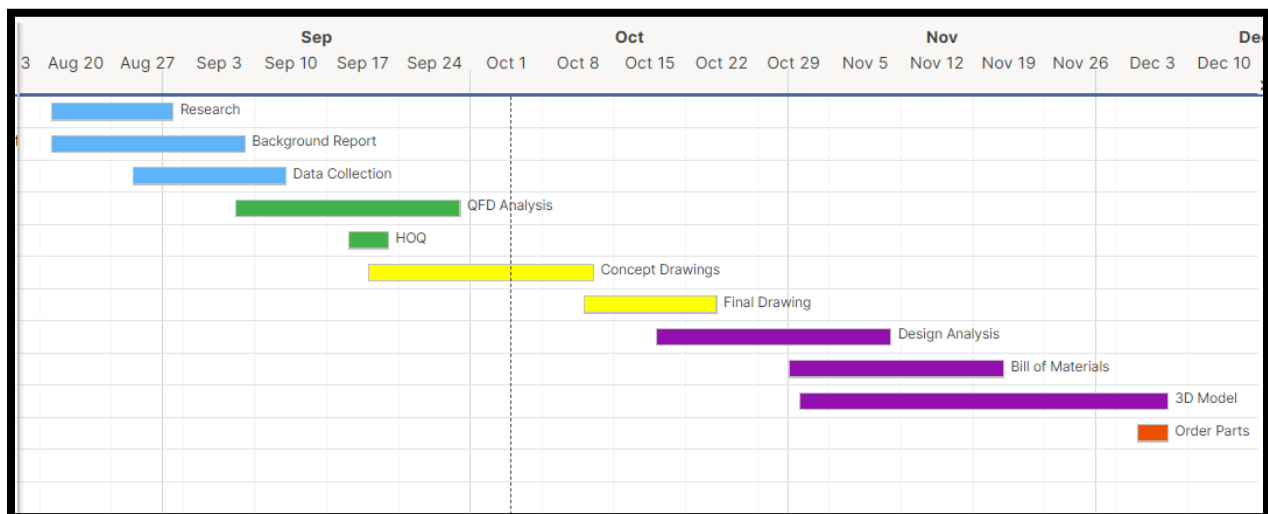
## Proposal:

### Project Budget Limit Proposal

- \$20,000

### Key Milestones and Proposed Schedule

Primary Column	Start Date	End Date
Research	08/21/23	09/01/23
Background Report	08/21/23	09/08/23
Data Collection	08/29/23	09/12/23
QFD Analysis	09/08/23	09/29/23
HOQ	09/19/23	09/22/23
Concept Drawings	09/21/23	10/12/23
Final Drawing	10/12/23	10/24/23
Design Analysis	10/19/23	11/10/23
Bill of Materials	11/01/23	11/21/23
3D Model	11/02/23	12/07/23
Order Parts	12/05/23	12/07/23



## Proposed Testing and Fabrication Timeline

### Project Budget Limit Proposal

- \$50,000

### Key Milestones and Proposed Schedule

The proposed timeline was constructed before automation came into the project. Key milestones for this timeline is the kick off date for electrical work and pneumatic plumbing of mid-March. The other milestone is the finalization of troubleshooting and the machine launch by the end of June.

## PROPOSED TIMELINE

TASK	DECEMBER	JANUARY	MARCH	APRIL	MAY	JUNE
ORDER PARTS	████████████████████					
ASSEMBLY		████████████████████				
ELECTRICAL WORK			████████████			
AIR PLUMBING			████████████			
PLC PROGRAMMING				████████████		
TROUBLESHOOTING					████████████	
MACHINE STARTUP					████████████	
TRAINING						████████
MACHINE LAUNCH						██████████



## **Conclusion**

In conclusion, the project is projected to finish in the coming year and is on track to successfully launch. There is still work needed to be done to ensure all parts variants can be efficiently ran and decrease cycle times across the board. With the use of automation being a new standard in the Aftermarket area, everything needs to be accounted for before replacing the manual processes. This includes all parts, operator training, and in house knowledge on the machine. Overall, the project has been a good learning experience for me and the team involved and seeing how the project has evolved since the start in August of 2023.

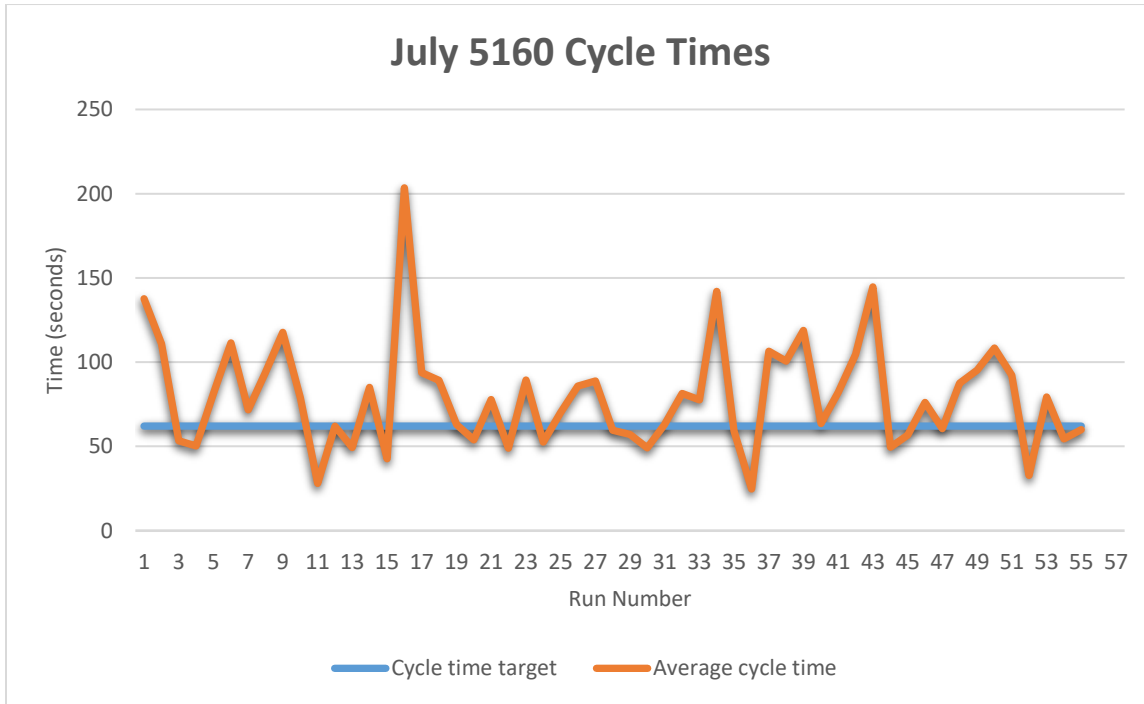
## **References:**

### **References**

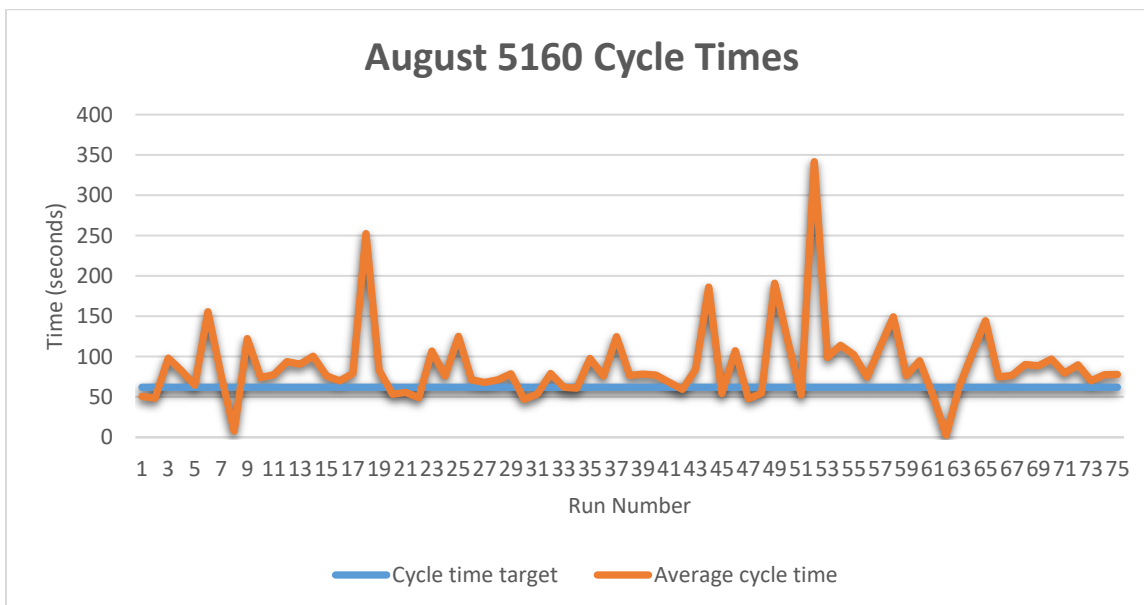
1. **SAP. s.l. : PartnerEdge, 2023.**
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3. **Massey, Keenan. *M500 Rounting Vs Actual Cycle Time.* 2023.**
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5. **MES Operation Center. *Data Collection.* 2023.**

# Appendices

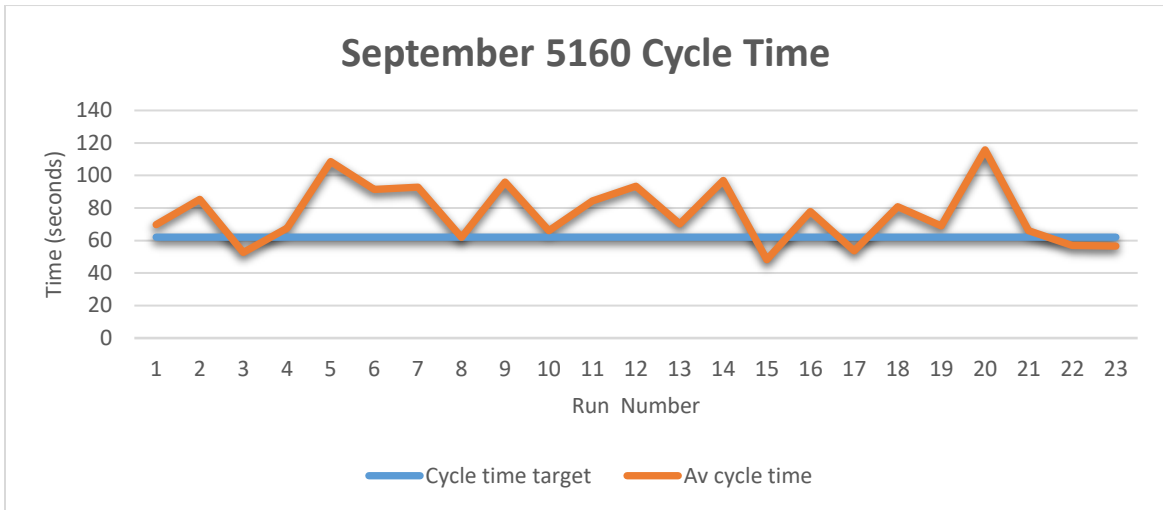
## Section 1.A



## Section 1.B



**Section 1.C**



**Section 2.A**

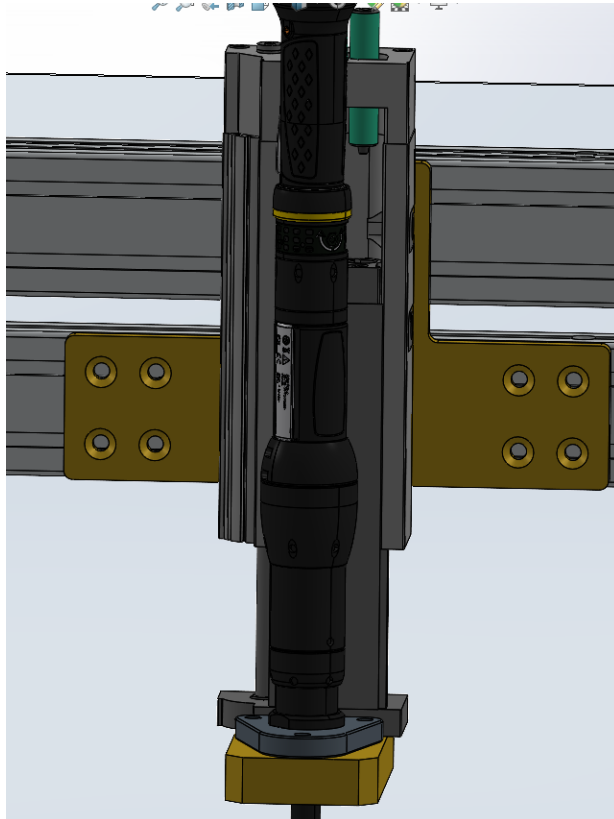
5160 Monthly Numbers 2023			
April		July	
Actual Part Total	2876	Actual Part Total	5773
Average Cycle	86	Average Cycle	80
Target Cycle	62	Target Cycle	62
Time Difference	23	Time Difference	18
Total Run Time (hr.)	68	Total Run Time (hr.)	128
Target Part Count	3963	Target Part Count	7404
Part Total Difference	1087	Part Total Difference	1631
Difference Cost (\$)	86953.34	Difference Cost (\$)	130509.43
May		August	
Actual Part Total	6491	Actual Part Total	8426
Average Cycle	93	Average Cycle	89
Target Cycle	62	Target Cycle	62
Time Difference	31	Time Difference	27
Total Run Time (hr.)	167	Total Run Time (hr.)	208
Target Part Count	9693	Target Part Count	12079
Part Total Difference	3202	Part Total Difference	3653
Difference Cost (\$)	256126.45	Difference Cost (\$)	292233.73
June		August	
Actual Part Total	2622	Actual Part Total	2837
Average Cycle	83	Average Cycle	77
Target Cycle	62	Target Cycle	62
Time Difference	21	Time Difference	15
Total Run Time (hr.)	61	Total Run Time (hr.)	60
Target Part Count	3523	Target Part Count	3501
Part Total Difference	901	Part Total Difference	664
Difference Cost (\$)	72069.40	Difference Cost (\$)	53099.29

### Section 3.A

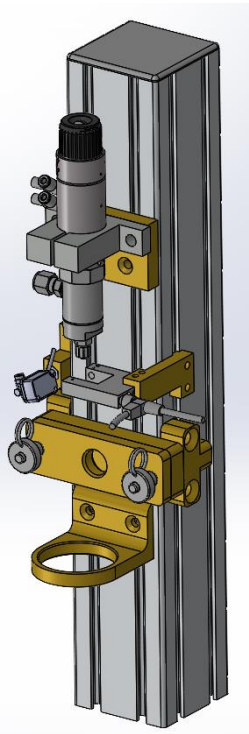
#### 5160 Part Breakdown



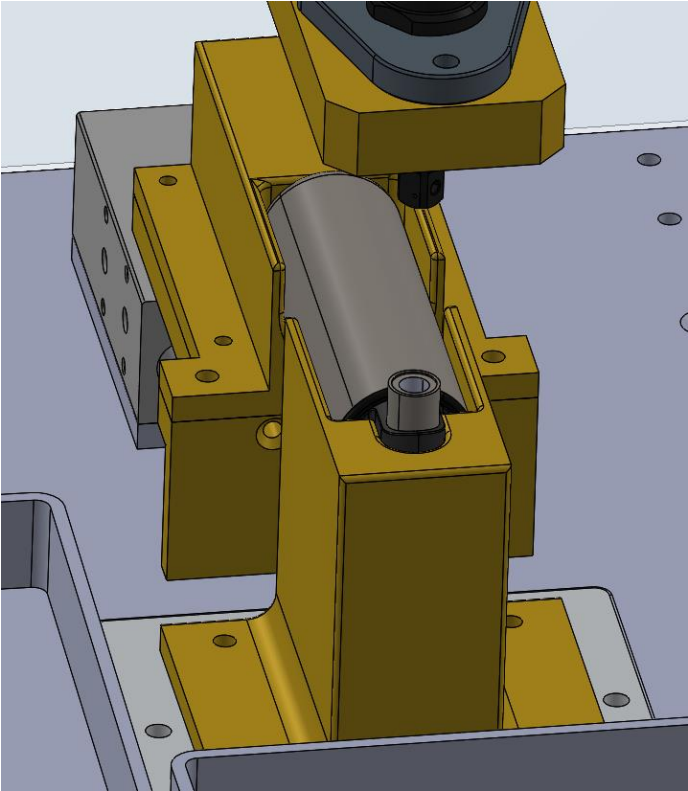
### Section 4.A



**Section 4.B**



**Section 4.C**



**Section 4.D**

