Semi-Automatic Ergonomic Nutritional Laboratory Container Opener

BME 200/300

December 11th, 2016

Client: Robert Radwin

Advisor: John Puccinelli

Team Members: Scottland Adkins, Crysta Frank, Nick Haller,

Hunter Higby, Katie Werth

Abstract

Laboratory procedures often necessitate extensive use of wrists and hands. The current procedure at a local nutritional laboratory involves each technician opening a significant amount of containers each day, invoking tremendous stress and strain on the hand, wrist and fingers. A device is desired by the laboratory to significantly reduce this hand strain during the repetitive opening of containers. While manual and automatic container-opening devices are currently on the market, they are targeted for consumer use rather than industrial or laboratory use. More specifically, the majority of automatic container-opening devices do not have the power to open containers fast enough for the technicians of concern, thus these devices would reduce their productivity. A new, automatic device is being proposed to specifically meet the technician's needs; most importantly, the device will be designed to significantly reduce hand strain without negatively affecting workflow patterns.

Table of Contents

Introduction

In industrial and laboratory settings, manual repetition of capping and uncapping containers by technicians and other employees causes significant stress and strain on their hands, wrists and fingers [1]. While several devices exist for assistance in opening containers in a household setting, no devices have proven successful for repetitive applications in industrial and laboratory settings [2]. The lack of an adequate product is especially problematic for technicians in laboratories that open more than 50 containers in a continuous manner each day. It is crucial to develop an alternative method of repetitively opening variably-sized containers to ensure that these repercussions are avoided.

Existing Devices

Manual Container Opener

Manual openers are one type of product on the market designed to simplify the process of opening containers. While this product eliminates a significant amount of the grip force required to open a container, the design still requires the user to exert a twisting force. In repetitive applications, this action is still capable of inducing unnecessary hand strain. Furthermore, implementing the use of a manual container opener would create an additional step in the technician's procedure, which would likely disrupt their workflow.

Figure 1: A manual container opener that is currently on the market. This particular design accommodates several container sizes [3].

Automatic Container Opener

Automatic container openers are another type of product that is currently on the market. Automatically operated openers are beneficial because they are capable of eliminating almost all of the force required by the user, but are often not as efficient as manual opener devices. Since the majority of products of this type require the use of a gripping mechanism for both the lid and the container, implementation in a laboratory setting would undoubtedly disrupt workflow patterns [4]. Additionally, most automatic container openers require the user to press a switch during the duration of the container opening process since they lack the technology to automatically turn off once the lid has been removed, which would further impact workflow. This style of container opener has also been reported to produce excessive noise and lack durability in industrial uses [5].

Figure 2: An automatic container opener that is currently on the market. This device contains clamping mechanisms at both ends of the device to accommodate several container and lid sizes [6].

Problem Statement

A large, commercial food-testing laboratory employs over 400 technicians that are required to repeatedly cap and uncap laboratory containers. Each technician follows a procedure, which involves the capping and uncapping of 50-100 containers per day. The repetitive counter-twisting motion that these technicians exhibit each day results in significant strain on their hands, wrists and fingers. The objective is to reduce this discomfort by developing a container opener tool or stationary fixture that assists in the opening of variably-sized containers.

Background

Articular cartilage, which covers the ends of bones, provides a smooth surface to allow healthy joints to function effortlessly [7]. Consistent stress and strain on a localized joint can degrade this cartilage and cause further pain and discomfort. Osteoarthritis is a common problem that results from the wearing away of cartilage in the basal joint of the thumb, leading to sharp pain and aching [1]. One who repeatedly engages in the counter-twisting motion that is required to open containers is at risk for developing basal joint arthritis, as the repetitive motion is capable of inducing cartilage degeneration.

Client Information

The client, Dr. Radwin, is affiliated with the Industrial and Systems Engineering and Biomedical Engineering programs at the University of Wisconsin-Madison. He collaborates with a local nutritional laboratory that has an interest in the well-being of their employees from an ergonomic standpoint.

Design Specifications

The client desires a product that is able to uncap up to 5,000 laboratory containers of various sizes each day while reducing the stress and strain of the hands, wrists and fingers of the laboratory technicians. The device must be easily integrated into the technician's current procedures without negatively impacting their workflow patterns or production. It is essential that the device is both accessible and easy to use in order for the technicians to maintain productivity while using the product. Additionally, the electrical and motorized components of the device should have a lifetime of at least 10,000 hours and the structural components should remain intact for at least 10 years. The device must open containers that are regularly encountered in the laboratory (ranging from 1.25” to 3.5” in diameter) and, since the device will be used to open nutritional containers, be able to undergo a simple sterilization procedure. The product should cost no more than standard laboratory equipment, which is generally about $500 to $1000. Full Design Specifications are included in Appendix A.

Preliminary Designs

Manual Container Opener

The first design is a manual torque-increasing device that incorporates a variety of sizes of circular molds on a single device in order to accommodate a range of container sizes. The material used to fabricate this product is a semi-rigid polymer that is capable of both deforming to match the diameter of a container and provide stability to exert a twisting motion. The user selects the size on the device and slips the product around the cover of the container. The user then deforms the sides of the device to provide a manual clamping function. The device acts as a lever to increase the torque being applied to the lid while the user holds the bottom of the container. This design is simple in terms of fabrication, and would significantly increase the torque that the user comfortably and consistently applies. This design does, however, require manual intervention that would slow down the user’s workflow and may not significantly reduce the hand strain required for the user to apply.

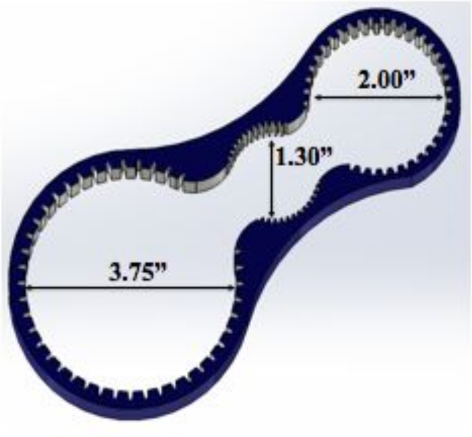


Figure 3: Manual Container Opener drawn in SolidWorks. The overall length of this device is 7.25”.

Clamp Hold Container Opener

The Clamp Hold Container Opener consists of a base clamp that holds onto the container and a top clamp that lowers onto the lid, both fabricated using a high-friction polymer. The top clamp operates by using a set of anti-parallel racks around a single pinion, which rotates to bring the two halves of the clamp together. Once the clamp halves obtain a secure hold on the lid, the pinion provides the necessary torque to uncap the lid from the container. This design is adaptable to many container sizes, both in height and diameter, and contains a durable steel structure. However, it requires significant setup as each container must be centered precisely and the motor only begins to remove the lid once the pinion has rotated enough to completely close the clamp.

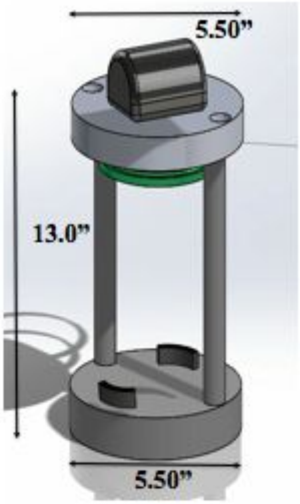


Figure 4: Clamp Hold Container Opener drawn using SolidWorks

Friction Hold Container Opener

The Friction Hold Container Opener design consists of an aluminum or durable plastic cone with a high-friction interior coating mounted to a motor on a steel frame. To operate, the user pushes the lid into the cone to activate the motor while holding the container to provide counter torque while the lid is removed. This design easily adapts to various container heights and lid diameters, has potential to improve workflow, and significantly reduces wrist and finger strain. On the other hand, it does not remove hand strain altogether, as the user is still required to grasp the bottom portion of the container.

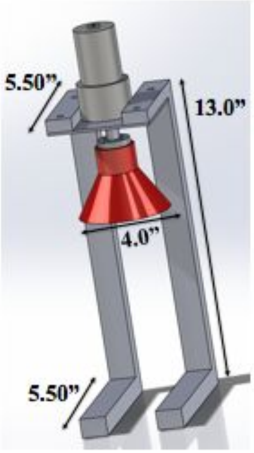


Figure 5: Friction Hold Container Opener drawn using SolidWorks

Pneumatic Container Opener

This design consists of a pneumatically operated clamp that grabs the sides of the container, along with a pneumatically operated clamp that lowers onto the lid and rotates to remove the it. Both clamps are fabricated out of a high-friction polymer to provide adequate grip to the container and lid. This design is be capable of clamping quickly, generating a large amount of torque, and is contains a durable steel structure. However, the Pneumatic Container Opener would require either a loud compressor, access to a compressed air supply, or pressurized air tanks which are not appealing to users and encompass dangerous component failure modes.

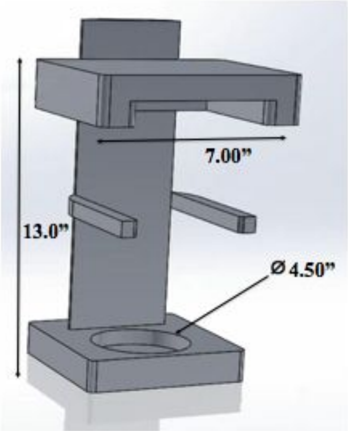
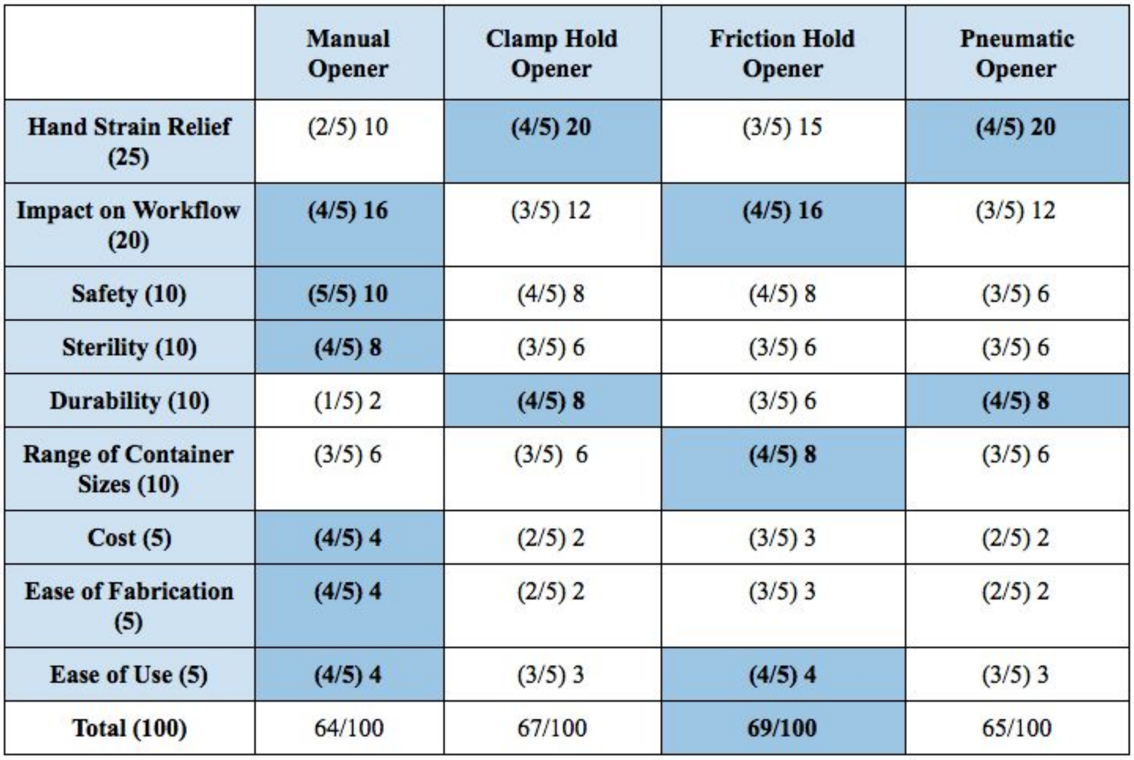


Figure 6: Pneumatic Container Opener drawn in SolidWorks.

Preliminary Design Evaluation



	Manual Opener	**Clamp Hold Opener**	**Friction Hold Opener**	**Pneumatic Opener**
Hand Strain Relief (25)	(2/5) 10	**(4/5) 20**	(3/5) 15	**(4/5) 20**
Impact on Workflow (20)	**(4/5) 16**	(3/5) 12	**(4/5) 16**	(3/5) 12
Safety (10)	**(5/5) 10**	(4/5) 8	(4/5) 8	(3/5) 6
Sterility (10)	**(4/5) 8**	(3/5) 6	(3/5) 6	(3/5) 6
Durability (10)	(1/5) 2	**(4/5) 8**	(3/5) 6	**(4/5) 8**
Range of Container Sizes (10)	(3/5) 6	(3/5) 6	**(4/5) 8**	(3/5) 6
Cost (5)	**(4/5) 4**	(2/5) 2	(3/5) 3	(2/5) 2
Ease of Fabrication (5)	**(4/5) 4**	(2/5) 2	(3/5) 3	(2/5) 2
Ease of Use (5)	**(4/5) 4**	(3/5) 3	**(4/5) 4**	(3/5) 3
Total (100)	64/100	67/100	**69/100**	65/100

Figure 7: Design Matrix

Hand Strain Relief

Hand Strain Relief was a criterion that was stressed greatly by the client, making it the most important testing criteria. The main goal of the design is to significantly reduce the stress and strain on a technician's hands, wrists and fingers during the opening of containers. Therefore, the highest ranked designs in this category represent the devices that provide the greatest relief, which are the Clamp Hold Container Opener and Pneumatic Container Opener. Both designs include a clamping mechanism at the base of the device that stabilizes the container while the rotating mechanism twists the container cover. The Manual Container Opener requires a significant amount of counter-twisting by the user, and the Friction Hold Container Opener requires the user to hold the base of the container while the cone semi-automatically twists the cover off of the container.

Impact on Workflow

Impact on Workflow was an important criterion due to the quotas that technicians are required to meet in the laboratory. In order for employees to uncap and cap a high volume of containers each day, the device must not significantly interrupt their workflow. The highest ranked designs in this category are devices that most similarly relate to employee's workflow when manually opening containers. The Clamp Hold Container Opener and Pneumatic Container Opener both require the user to set the clamping mechanisms onto the base of the container being opened, which greatly slows down the user's procedure. Since the Manual Container Opener and Friction Hold Container Opener do not require the user to set clamping mechanisms on the base of the container prior to opening, they are considered to be more efficient devices, and are therefore ranked highest in this category.

Safety

Safety had a relatively high weight due to the consideration of the well-being of the user. Since the device will experience high usage each day, it must be reliable and have minimal risk for hazardous situations. The Manual Container Opener was rated highest since it does not contain any moving parts or dangerous components. The Clamp Hold Container Opener and Friction Hold Container Opener are both powered by compact DC gear motors, resulting in a lower safety rating in this case. The Pneumatic Container Opener would present significant risk to the user, as standard cylinder compressor pumps require about 70 PSI to function [8]. For these reasons, the Manual Container Opener was ranked highest and the Pneumatic Container Opener was ranked lowest in this category.

Sterility

Sterility was the third most important criterion and a crucial consideration due to the environment in which the device will be operated. In a nutritional laboratory, sterilization of all samples is vital to the accuracy of tests and evaluations. The top rated design in this category, the Manual Container Opener, is a device that can be sterilized easily and efficiently by any technician at any time. The remaining three designs are more complex in their components and assembly, making the sterilization of the structures more time consuming and intricate. For these reasons, the Manual Container Opener ranked the highest in this category, while the Clamp Hold Container Opener, Friction Hold Container Opener, and Pneumatic Container Opener were tied with a slightly lower score.

Durability

Durability was another important criterion due to the high traffic that the device will endure. Since each employee uncaps and caps 50-100 containers each day, and the device may be used by multiple employees, it must be capable of functioning under consistent usage while also requiring minimal maintenance. The Clamp Hold Container Opener and Pneumatic Container Opener are composed exclusively of high strength materials, while the Manual Container Opener and Friction Hold Container Opener involve the use of weaker strength materials such as plastic and silicone, respectively. For this reason, the Clamp Hold Container Opener and Pneumatic Container Opener achieved the highest ranking in this category.

Range of Container Sizes

Range of Container Sizes had a relatively high weight in the evaluation of the four designs. The final design should accommodate all of the container sizes requested by the lab, which range from 1.25” to 3.5” in lid diameter. The Friction Hold Container Opener is capable of opening a wide variety of sizes of containers due to the cone mechanism that contacts the container cover. The Manual Container Opener, Clamp Hold Container Opener, and Pneumatic Container Opener are capable of interacting with approximately the same range of container sizes. The Clamp Hold Container Opener and Pneumatic Container Opener contain similar clamping mechanisms to stabilize the base of the container, and the Manual Container Opener is restricted to the diameters of each ring. Hence, the Friction Hold Container Opener was ranked highest in this category.

Cost

Cost had a relatively low weight in the evaluation. The laboratory is interested in a device that significantly decreases the level of discomfort that technicians are experiencing, and has not established a strict cost limit on the device. The Manual Container Opener requires only two materials (plastic and silicone), neither of which are particularly expensive. The Friction Hold Container Opener involves a motor along with an aluminum structure, hub, and cone with a silicone interior, and the Clamp Hold Container Opener requires a greater volume of the same materials. The Pneumatic Container Opener involves integration of a motor, cylinder, and valves in addition to a metal structure. For these reasons, the Manual Container Opener scored highest in this category.

Ease of Fabrication

Ease of Fabrication was the lowest-weighted category. While it is important that the design is feasible, it is not crucial that the fabrication process is simple. The Manual Container Opener, again, requires the least components and does not include a motor of any kind. The Friction Hold Container Opener is more complex, but does not necessitate an unfeasible fabrication process. The Clamp Hold Container Opener and Pneumatic Container Opener would be the most difficult to fabricate due to the addition of the clamping mechanism at the base of the device. Hence, the Manual Container Opener was ranked highest in this category.

Fabrication and Development Process

Materials

The container opener device needed to be fabricated using materials that were durable and would withstand constant use for many years. The structural aspects of the final prototype are composed of (unknown) steel alloys. One inch by one inch tubular steel was chosen for its strength and affordable cost. In contrast, two ½" solid steel plates were chosen for the base of the device due to their density. The weight that the steel plates provide at the base of the device improve the stability of the device during use. 2" by 2" angled steel was used to fabricate the four angle brackets that secure the structural components (tubular steel to tubular steel and tubular steel to steel plates). Angled steel was chosen for its strength and because the material matched the other structural components, providing a more secure connection. A ⅛" aluminum plate was selected for use as the motor mounting plate due its low cost and ease of fabrication. For these same reasons, 1" by 1" angled aluminum was selected to use for the switch mounting bracket. Cylindrical aluminum was chosen for fabrication of the hub due to its ease of fabrication as well. The fasteners featured in the device include ¼-20 hex bolts, ¼-20 socket head cap bolts, ¼-20 hex nuts, 10-32 hex nuts and a ¼-inch set screw. The ¼-20 nuts and bolts were selected as fasteners for the device because of their durability and common access. The cone was 3D printed out of ABS plastic due to ease of fabrication and the material's strength and durability. Silicone caulk was applied as the coating inside the cone due to its high-friction properties and its ability to be reapplied as necessary. A full materials and expense list is available in Appendix B.

Methods

All structural materials were purchased from the CoE shop and needed to be machined for assembly in the final design. A 36" piece of inch by inch tubular steel was cut into two 5" and two 13" pieces using a drop saw. The holes that were necessary for the tubular steel pieces were measured using a calipers and marked using a punch. The holes were then drilled out using a drill press. The two ½" thick steel plates were purchased in the correct size and did not require further fabrication. The holes for the steel plates were measured and drilled using the same methods that were used for the tubular steel. A 4" long piece of 2" by 2" angled steel was purchased, measured into four 1" pieces using a calipers, and then cut using a drop saw. The aluminum motor mounting plate was cut to the correct dimensions using the bandsaw, and a mill was used to drill the holes in the aluminum plate to ensure accuracy. The aluminum switch mounting bracket was also cut to size using the bandsaw, but the holes for the bracket were measured using the calipers and drilled using the drill press. The most complicated aspect of the design fabrication was the hub. The hub was fabricated from a 3.5" by 3.5" cylindrical piece of aluminum and was lathed to a maximum diameter of 2.5" and a height of 1". The mill was used to create the holes for the hub. Complete dimension drawings for each component can be found in Appendix C.

Upon fabrication of all individual components of the device, the final product was assembled using the proper bolts and nuts according to the SolidWorks sketch of the Friction Hold Container Opener presented earlier in **Figure 5**. The same SolidWorks sketch is also shown in Appendix D. Loctite was added to all nuts and bolts to increase the stability and lifetime of the device. Lastly, the switch was properly wired to the motor and positive and negative leads were added in a way that resulted in a counterclockwise rotation of the cone. A schematic of the circuitry is shown in Appendix E.

Final Prototype

The final prototype features the DC gear motor at the top of the device, which is mounted to an aluminum plate. Also attached to the aluminum plate are the horizontal structural components. Steel angle brackets connect the horizontal structural components to the vertical structural components, along with the bottom plate to the vertical structural components. The aluminum fabricated hub connects the motor to the 3D printed cone, leaving a small gap between the bottom of the hub and the top of the cone. The snap-action switch is mounted to the aluminum plate at the top of the device by the aluminum fabricated mounting bracket, and is positioned in such a way to activate when pressure is applied upwards into the cone. To power the final prototype, the switch, motor and power source are wired according to the schematic in Appendix E.

Figure 8: The final prototype in action. A user presses the container upwards into the cone, causing a snap-action switch to activate the motor. The motor revolves the high friction cone (clockwise) until the cover is removed. The user relieves the pressure from the container stopping the motor.

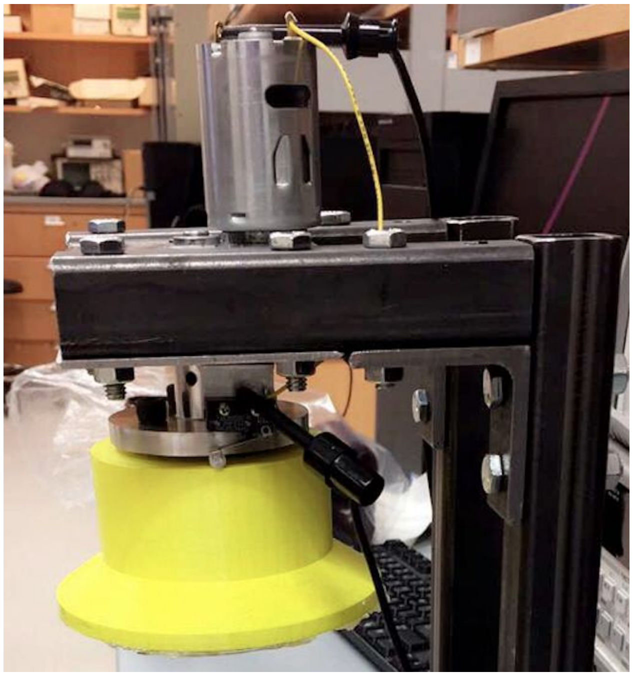


Figure 9: Motor/hub/switch/cone assembly

Testing

Workflow Impact Testing

A test was developed and performed in order to analyze the speed at which the final device opens containers compared to the speed at which a user can manually open containers, which allowed us to determine whether the device impacts workflow patterns. First, 50 containers of the same size were opened using the device, and the time was recorded. To compare this to manually opening containers, a team member opened the 50 containers of the same size and recorded their time. This procedure was repeated six times using the 2.19" ("large") container and six times using the 1.74" ("medium") container. The test was performed exclusively on these two container sizes because they are the most frequently opened containers by technicians at the local laboratory.

To quantify the results of the impact on workflow testing, a two-sided t-test was completed. We developed two hypotheses for the t-tests, a null hypothesis and an alternative hypothesis. The null hypothesis assumed that the user could open containers at the same rate using the device in comparison to opening containers manually. The alternative hypothesis assumed that the user could open containers at a significantly different rate using the device in comparison to opening containers manually. The p-value of the t-test determines whether the null hypothesis can be accepted or rejected. We expect that our testing outcomes will show that a user that is assisted by the device opens containers at the same speed or faster than a user that opens the containers manually. This would be the ideal result, as it would conclude that our device does not negatively impact the workflow of the technicians.

Hand Strain Relief Testing

A test was performed in order to analyze the amount of hand strain relief that the device provided to the user. First, users were asked to record the hand strain they experienced on a scale of 0-5 (5 representing unbearable hand strain) upon manually opening 50 containers in a row, as previously described. Similarly, team members were asked to record the hand strain they experienced on a scale from 0-5 upon opening the same 50 containers using the device.

Again, a two-sided t-test was completed in order to quantify the level of hand strain relief that was provided by the use of the device, and two hypotheses were constructed. The null hypothesis assumed that the device caused the same level of strain on the user's hand in comparison to manually opening containers. The alternative hypothesis assumed that the device resulted in a significantly different level of strain on the user's hand in comparison to manually opening containers. The p-value of the t-test determines whether the null hypothesis can be rejected or accepted. We expect that our testing outcomes will show lower levels of strain on the user's hand upon use of the device, and will allow for rejection of the null hypothesis. This would be the ideal result, as it would conclude that the use of the device significantly lowers the level of hand strain experienced by a user upon repetitively opening containers.

Silicone Coating Degradation Testing

The third test that was performed on the device was a qualitative assessment of the durability of the high-friction silicone coating. An initial picture of the silicone coating in the cone was taken before any containers were opened using the device (see **Figure 12**). Upon completing the workflow testing for the device, which consisted of opening a total of 600 containers, another picture of the silicone coating in the cone was taken. The two pictures were compared to determine the effect opening 600 containers had on the wear of the silicone coating.

Sources of Error or Variance

The standard deviation and variance in manually-opened container data stems from human error. More specifically, it comes from the variation in users completing the trials. Trials that measured the time taken to manually open containers were conducted by two different group members, meaning variance could have occurred in timing, coordination, or environment. The variance in the hand strain data is due to subjectivity of the test. It is highly unlikely that the three group members that reported hand strain levels have identical pain tolerance.

Results

Statistical Analysis

Results from each test are shown in Appendix G. Both container sizes that were opened manually and with the device displayed similar averages for the two testing methods that were conducted. The standard deviations of the large and medium containers being opened using the device and manually were relatively small, however it is important to note that the standard deviations in time while using the device were slightly smaller than when containers were opened manually. The variances for the opening of the containers followed the same pattern as the standard deviations. Using a significance level of alpha = 0.01, the p-values were found to be 0.0264 and 0.129 for the large containers and medium containers, respectively. The two-sided t-tests performed for both the large and medium containers at the given significance level showed that we do not have significant statistical evidence to reject the null hypothesis. This means that there is not sufficient evidence to conclude that the device negatively impacts workflow. A graph of the average time to open 50 containers manually and using the device is shown in **Figure 10**.

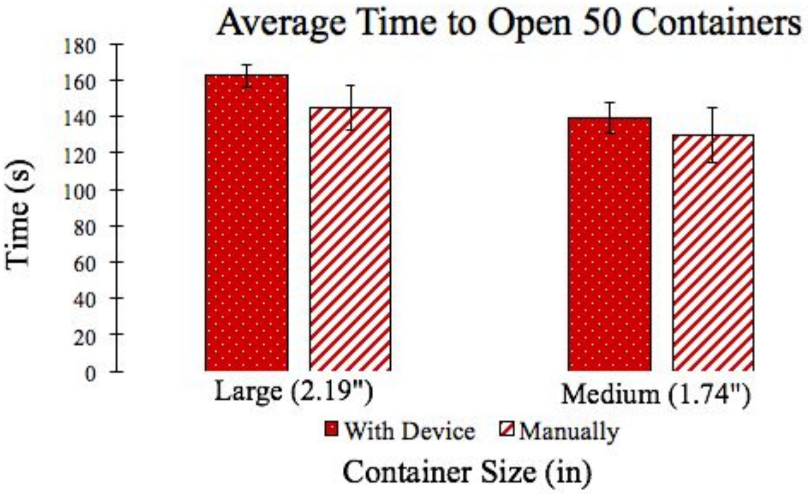


Figure 10: The average time taken to open 50 containers manually and with the device. Error bars denote 95% confidence intervals and are included to show the variance between trials.

The results for hand strain relief agree with the prediction that the device would significantly reduce hand strain. The average hand strain reported for manually opening both container sizes were similar, the large containers having a slightly larger hand strain reporting. This was expected from the information that was received from the technicians when visiting the local lab. Likewise, the standard deviations and variances for hand strain from manually opening containers were miniscule for both sizes, showing that opening containers manually consistently leads to the same amount of hand strain. When comparing the hand strain experienced from manually opening the containers to the hand strain reported when using the device it is extremely clear that the device significantly reduces hand strain. During all twelve trials of using the device for both container sizes, the user reported no hand strain. The two-sided t-tests performed on hand strain relief for both container sizes at the given significance level allowed us to reject the null hypothesis. The p-values for the large and medium containers were 0.000048 and 0.000105, respectively. Using a significance level of alpha = 0.01 we are able to conclude that there is sufficient statistical evidence that opening containers with the device alters the amount of hand strain experienced by the user. Using the information stated above regarding average hand strain reported by the user, standard deviation, and variance in hand strain we are able to conclude that the device significantly reduces hand strain. A simple comparison of the average hand strain reported when using the device and when opening containers manually also depicts this result very clearly, see **Figure 12**.

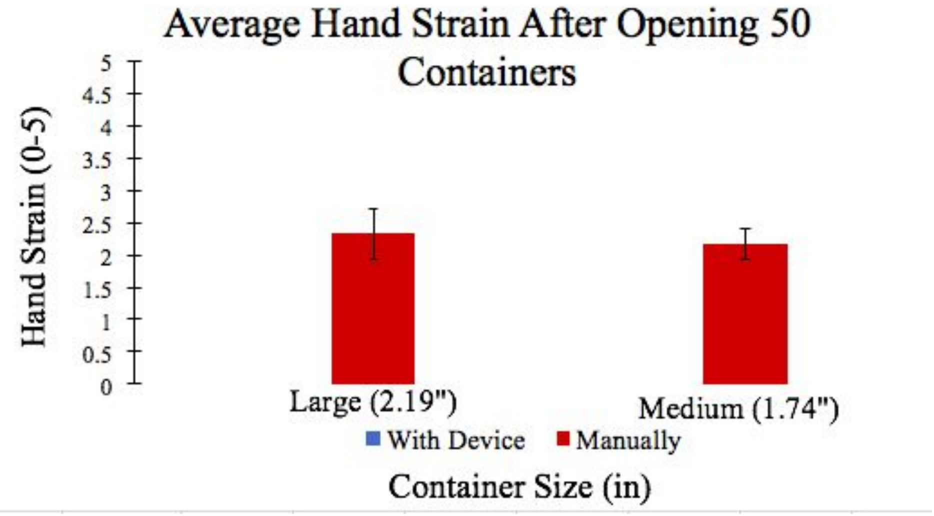


Figure 11: The average hand strain reported by the user after opening 50 containers manually and with the device. Error bars denote 95% confidence intervals and are included to show the variance between trials.

The qualitative comparison of the wear on the silicone coating showed results that were more successful than expected. Following the opening of 600 containers the silicone coating showed very minimal degradation. Actual pictures of the degradation can be seen in **Figure 12.** When analyzing the silicone coating, only one minute spot of degradation is apparent. This qualitative test supports the durability of the high-friction coating.

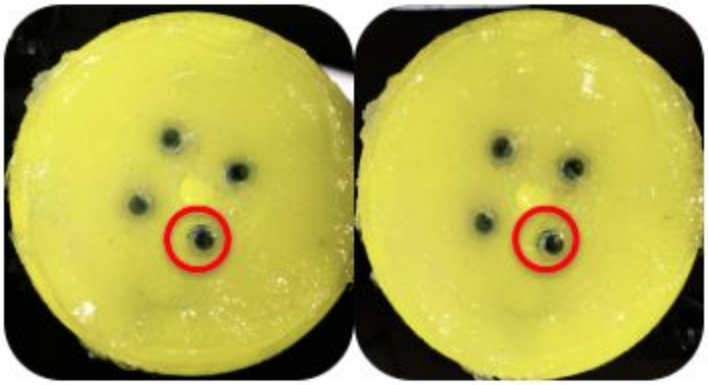


Figure 12: Interior of the cone as a result of continuous opening of containers. *Left:* high-friction silicone coating prior to opening. *Right:* high-friction silicone coating upon opening approximately 600 containers. Minimal wear is evident on the coating after use, only one small area portrays any loss of coating after testing, denoted by red circles.

Discussion

Implications of Results

The device proved to be an effective solution for the technicians needs in all aspects of testing. The technicians stressed two main factors for the device; hand strain relief and impact on workflow. The testing that was completed to measure the impact on workflow showed that there using the device would not significantly impact workflow. The t-test comparing the time to open large containers using the two methods did not show significant difference, however, the small p-value is apprehensive and should be further examined. The small p-value found when comparing the manually-opened large containers to the device-opened large containers can be attributed to human error within the trials, as well as the small sample size. When manually opening the containers, team members attempted to work at a pace that was likely much faster than a technician's daily routine. Furthermore, a sample size of six is not substantial, which can lead to more variation in data and less accurate results. To further portray that the device would not significantly impact the workflow, a comparison between the slowest time to open 50 large containers using the device and the fastest time to open 50 containers manually can be conducted. The comparison between these two values shows that, over the course of an entire work day, for a technician who opens 50 containers a day, using the device would only increase the technician's total workflow time by a maximum of 39 seconds. This value is the worst case scenario for the negative impact that the device would have on the technicians workflow. The t-test for the medium containers resulted in a larger p-value, which grants more confidence in the device not impacting workflow in a negative manner.

The decrease in hand strain provided by the device can clearly be seen in the device's testing results. The extremely small p-values found by the t-tests comparing the hand strain of both medium and large containers allows us to conclude that the device significantly reduces hand strain of the user with absolute certainty. A simple comparison of the average hand strain reported when using the device and when opening containers manually also depicts this result very clearly, see **Figure 11**.

Sources of Error

During fabrication of the device a drill press was used to create many of the holes in the steel structural components, which was not quite as accurate as using a mill would have been. This resulted in some holes needing to be filed in order to attach multiple components of the device to one another. The device is still sturdy, but if the holes had been drilled using a mill they may have been more accurate and allowed the device to be more secure and durable. Additionally, some clearances were not calculated accurately in the CAD model which resulted in only one bolt being used to secure L-brackets to the tubule steel instead of two bolts.

Conclusion

Technicians at a local commercial food testing laboratory open an excessive amount of containers each day. The continuous opening of containers exerts a tremendous amount of stress and strain on their hands, wrists and fingers. The aim of this project was to create a device that would assist technicians with the opening of containers in order to significantly decrease the hand strain experienced by the user.

The final device that was produced was proven to significantly decrease the hand strain of the user without negatively impacting the workflow. Although the device that was created met the requirements of the design, the speed at which the device opens containers could be improved to allow the device to positively affect workflow. During hand strain relief testing, users reported no hand strain after repetitively using the device. To fully automate the container opening process and eliminate hand strain altogether, an adjustable clamping mechanism could be implemented into the design. The implementation of this clamping device would require careful considerations so that it would not negatively impact workflow. Based on the criteria that was most greatly stressed by the client (reduction of hand strain and no impact on workflow) the final device that was produced proved to be successful.

Future Work

Although a working device was produced that met the client's requirements, there are additional steps that could be taken to improve the device. The final device accommodates containers with cover diameters of 1.25" - 3.5" . It would be beneficial to develop conveniently interchangeable cones to accommodate even more container sizes. The laboratory's Health and Safety Department will evaluate the device before it can be introduced to the laboratory space in which it will be used. It is important that any moving parts associated with the device meet the expectations that the Health and Safety Departments have established. Fabricating a protective shield to cover the cone, hub, and motor components of the device would further ensure safety of the device while in use. Also, more devices could be produced that are identical to the final design. This would allow more technicians access to a container opener, therefore reducing hand stress and strain for a greater percentage of laboratory employees. Furthermore, a cover for the wiring, and a clamp to secure the device to the laboratory table could be added to the product. Right now the wiring that connects the motor to the power supply is exposed. Covering these wires would lead to a safer, more professional design. The upward force applied to the cone to uncap the container causes the device to move during use. To counter this, a clamp could be used to fully secure the device to the laboratory table. Lastly, a power supply is needed for the device. The motor in the final device is a 24 V DC gear motor, meaning that it requires either a direct DC power supply or a AC to DC transformer.

Acknowledgements

The authors would like to extend their gratitude to Dr. Radwin (ISyE, BME), Dr. Puccinelli (BME), Christa Wille (BME), and members of the CoE Shop Staff for their assistance in the design process, fabrication and implementation of the Semi-Automatic Ergonomic Container Opener. Additionally, the authors would like to thank the partnered local laboratory for their unique request and confidence in the team's ability to satisfy their ergonomic needs.

References

[1] Rohde, Rachel, M.D. (n.d.). *A Nation in Motion*. American Academy of Orthopaedic Surgeons. Retrieved Sept. 29, 2016, from http://www.anationinmotion.org/ortho-pinion/trouble-opening-jars.

[2] Mah, Pat Y., and Mark Andrew Sanders. (n.d.) *Jar Opener*. US7398714B1. N.p., Retrieved 7 Oct. 2016, from https://patents.google.com/patent/US7398714B1/en?q=rack+pinion&q=jar+opener.

[3] Rmmh, Sandicrey, Lilfoodiegirl, SammyT, Nan5, Geegah, Dick107, Fanny, JLee, Ksoddball, Ksrc, Fred2, LisaH, Deirdre, GMom2, and Artgirl62. "Easi-Twist Jar Opener." *The Container Store*. N.p., 20 Mar. 2016. Web. 08 Dec. 2016.

[4] A. Yoxall *et al*., "Making Jam Jars Easier to Open: the inclusive engineering approach," Univ. Sheffield, Sheffield, UK, 2008. http://www.sparc.ac.uk/media/downloads/executivesummaries/exec_summary_yoxall.pdf.

[5] Information received during an interview with technicians during the visit to the laboratory. 10/13/2016.

[6] "Sears.com." *Sears.com*. Sears, n.d. Web. 08 Dec. 2016.

[7] "Wrist, Hand & Finger Pain." *Hand Arthritis | Arthritis Finger | Hand Pain*. Arthritis Foundation, n.d. Web. 11 Dec. 2016.

[8] Cagi. (2016). *Air Compressor Selection and Application.* N.p., Retrieved 10 Dec. 2016, from http://www.cagi.org/pdfs/cagiaircompressorhp.pdf

Appendix

Appendix A

Product Design Specifications

Ergonomic Nutritional Laboratory Container Opener
Preliminary Product Design Specifications

Scottland Adkins, Crysta Frank, Nick Haller, Hunter Higby, and Katie Werth

Function:

An ergonomic laboratory container opener is a device that is capable of opening variable sizes of laboratory containers with minimal effort exerted by lab technicians. Openers range from manually operated to entirely automatic. Manual openers are beneficial because they are able to open variable sizes of containers. However, they generally fail to require a low amount of force exertion from the user. Automatic openers are ideal in reducing user effort, but are often less lenient in the range of container sizes that they are capable of opening. A local commercial food testing laboratory that consists of over 400 employees, follows a protocol which requires multiple technicians to repeatedly cap and uncap up to 100 laboratory containers each day. The goal is to design a laboratory container opener that significantly relieves strain from lab technicians' hands and fingers.

Client Requirements:

The laboratory container opener must open containers with minimal manual intervention. It must be capable of opening laboratory containers in a variety of sizes; specific size range will be determined upon a tour of the laboratory. The container opener should operate in a timely manner and maintain function after excessive use. A budget has not yet been defined, but a reasonable cost for a product of this type would make it more attractive to relevant companies.

1. Physical and Operational Characteristics:
    a. Performance Requirements:
    The most important function of the opener is to open laboratory containers with minimal manual force. The jar opener must withstand excessive use (~5,000 containers per day) and function in a timely manner to accommodate the constant use of the device.

    b. Safety:

The design of the opener must account for potential device failures, and any harmful device components must be properly contained so that the user is not harmed by the laboratory container opener.

c. Accuracy and Reliability:
The container opener must function in a reliable, consistent manner to avoid setbacks in the lab.

d. Life in Service:
The laboratory container opener must maintain functionality while being used upwards of 5,000 times per day.

e. Shelf Life:
All materials used in fabrication of the opener must have abundant shelf lives to ensure that the container opener operates successfully over an extended period of time.

f. Operating Environment:
The container opener will be operated in a nutritional laboratory, meaning it must be sterile, resistant to potential spills, and able to withstand abundant use. The laboratory is room temperature.

g. Ergonomics:
The operation of the device must be straightforward and efficient for lab technicians to use.

h. Size:
At largest, the laboratory container opener should be small enough to be installed on a lab bench. The component of the opener which contacts the laboratory containers must be adjustable to account for variable container sizes.

i. Power Source:
The only potential device component that would require power is a motor, which would be powered through an outlet.

j. Weight:
The weight of the laboratory container is not entirely crucial, since it will be stationary. However, it must be light enough to be installed on the top of a lab bench without causing damage to the surface.

k. Materials:
   Metals, polymers, and plastics are all materials that could be used to fabricate the device. Additionally, to accommodate a variety of container sizes, rubber to grip the container and gears to adjust the size of the opener could also be utilized. The materials used must be capable of simple cleaning and sterilization.

l. Aesthetics, Appearance, and Finish:
   The opener must be functional and easy to handle. It should resemble a professional piece of laboratory equipment.

2. Product Characteristics:
   a. Target Product Cost:
      The target product cost of the device has not yet been specified, but will be within reason for the customer.

   b. Quantity:
      Ideally, a one-size-fits-all opener will be made to accommodate for various laboratory container sizes. Multiple openers will be made, if necessary, to cover all container sizes.

3. Miscellaneous:
   a. Standard and Specification:
      No additional approvals are necessary for this project.

   b. Patient-Related Concerns:
      The finished product must maintain sterility upon use, especially in areas that come into contact with laboratory containers.

   c. Competition:
      i. Manual Opener:
         Manual openers alleviate some strain from users when opening containers. However, since laboratory technicians must open an excessive amount of containers each day, this strain is still too great.

      ii. Automatic Opener:
         In general, automatic opener devices are operated by a single touch. They rotate around jars to open them, and are adjustable in size to open a variety of container sizes. However, these devices are quite small, require AA

batteries, and therefore are not entirely powerful. Additionally, it is not likely that their ranges are wide enough to open the variety of container sizes requested by the client.

d. Customer:
   The customer for this project is Covance, a globally known drug development and research company based in Madison, WI. The design will be made to open any style of container, research or household.

Appendix B

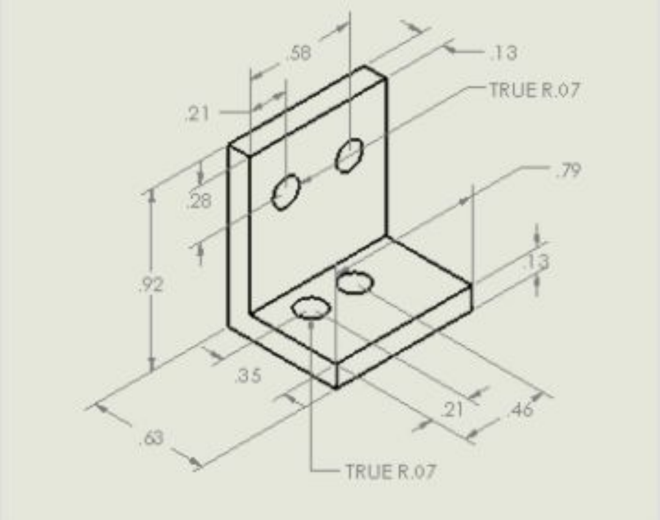
Parts List

Item	**Cost**	**Store**	**Part Number**
Paint brush/roller kit	$3.98	Menards	5618334
Compact DC Gear Motor	$53.16	McMaster-Carr	6409K26
Sensor	$3.52	McMaster-Carr	7658K12
Shipping	$5.27	McMaster-Carr	N/A
Silicone Caulk	$6.00	Home Depot	502030
Polyurethane Caulk	$6.00	Home Depot	184360
Caulk Gun	$2.00	Home Depot	449032
3D Printed Prototype Cone	$13.00	CoE Shop	N/A
3D Printed Cone	$89.66	CoE Shop	N/A
Hub Stock Material	$5.96	CoE Shop	N/A
Bolts (1/4-20, 6-32, set screw)	$1.73	CoE Shop	N/A
Nuts (1/4-20, 6-32, 10-32)	$0.24	CoE Shop	N/A
Loctite	$0.00	CoE Shop	N/A
Bar Steel	$17.14	CoE Shop	N/A
Angle Steel	$2.95	CoE Shop	N/A
Steel Plate	$9.32	CoE Shop	N/A
Aluminum Plate	$0.00	CoE Shop	N/A
TOTAL	**$219.93**		

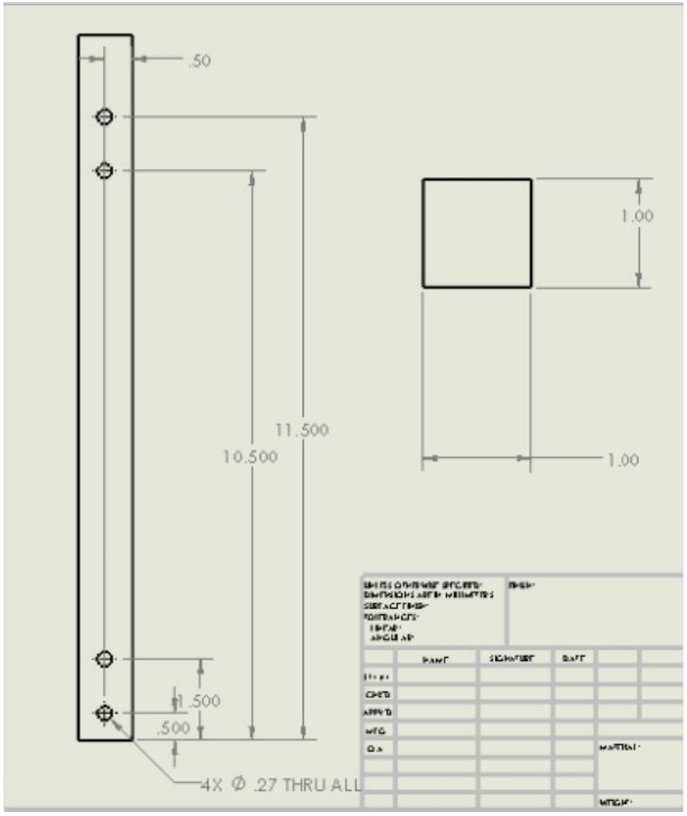
Appendix C

Dimension Drawings

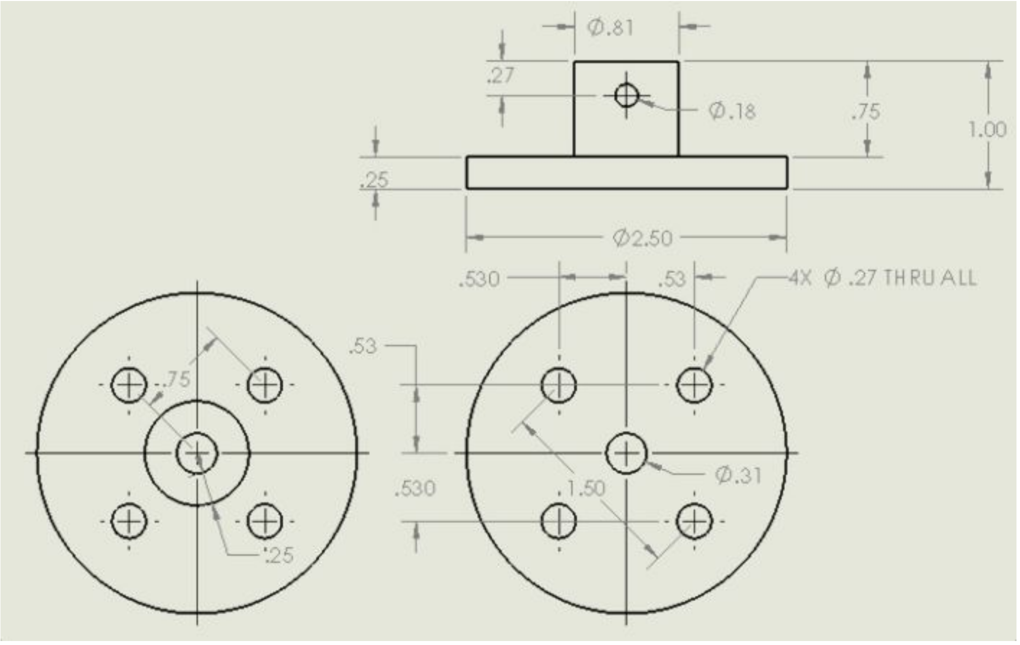
Switch Mounting Bracket



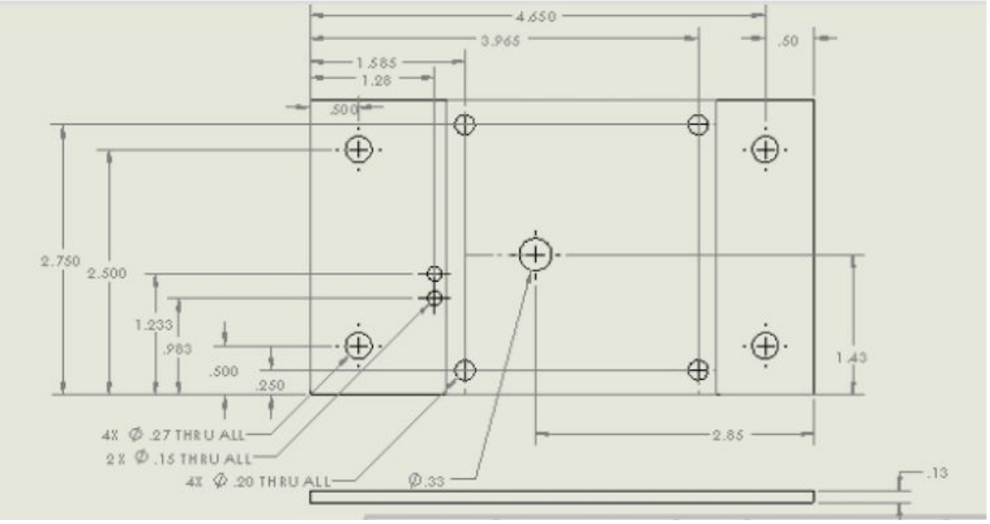
13” tubular steel



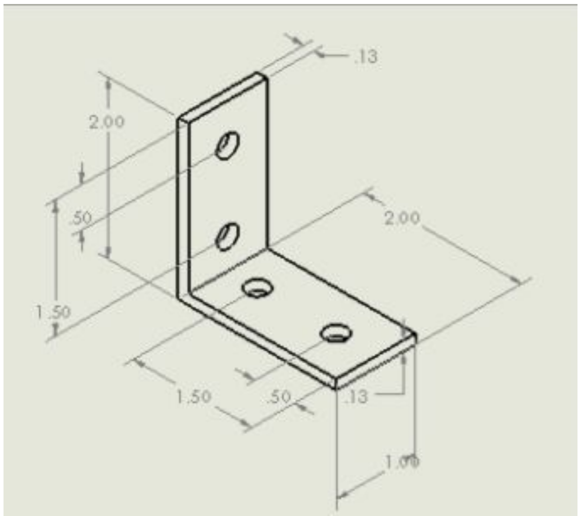
Hub



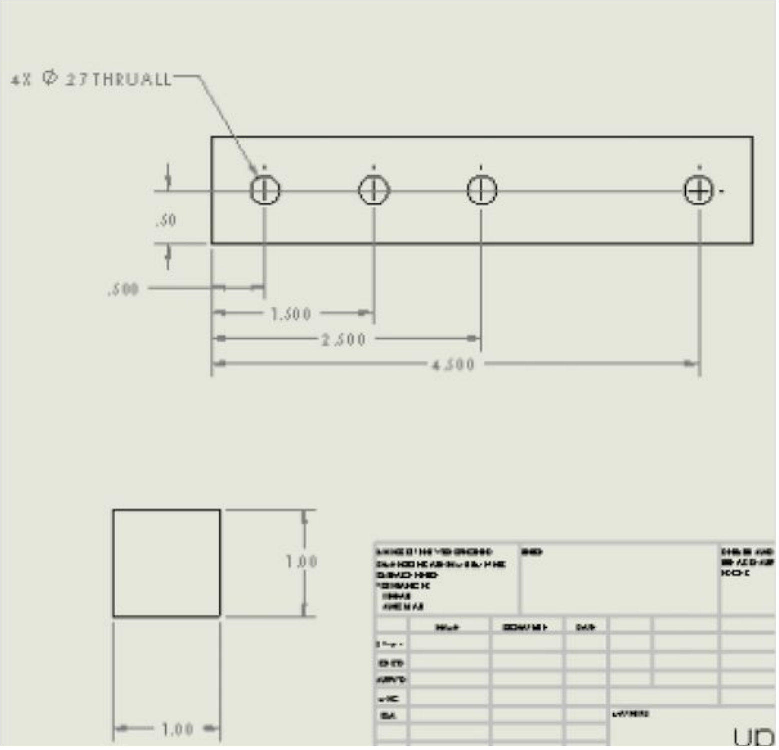
Motor Mounting Plate



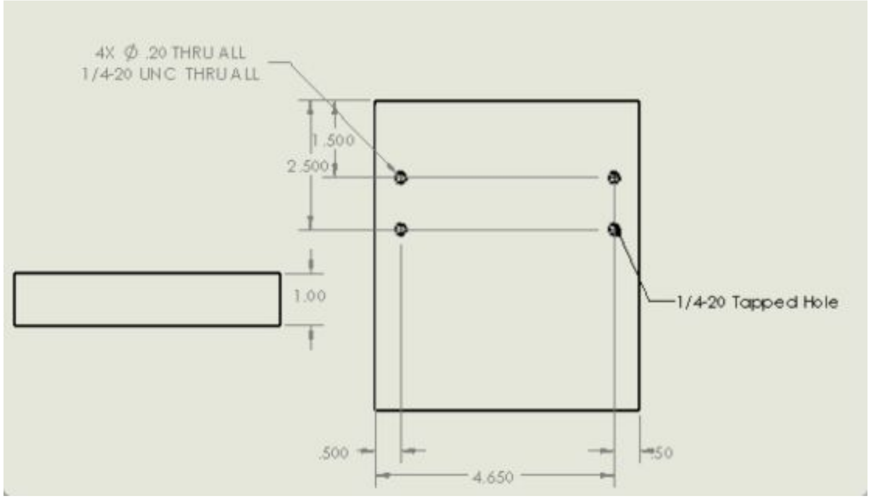
2” by 2” Bracket



5” Tubular Steel

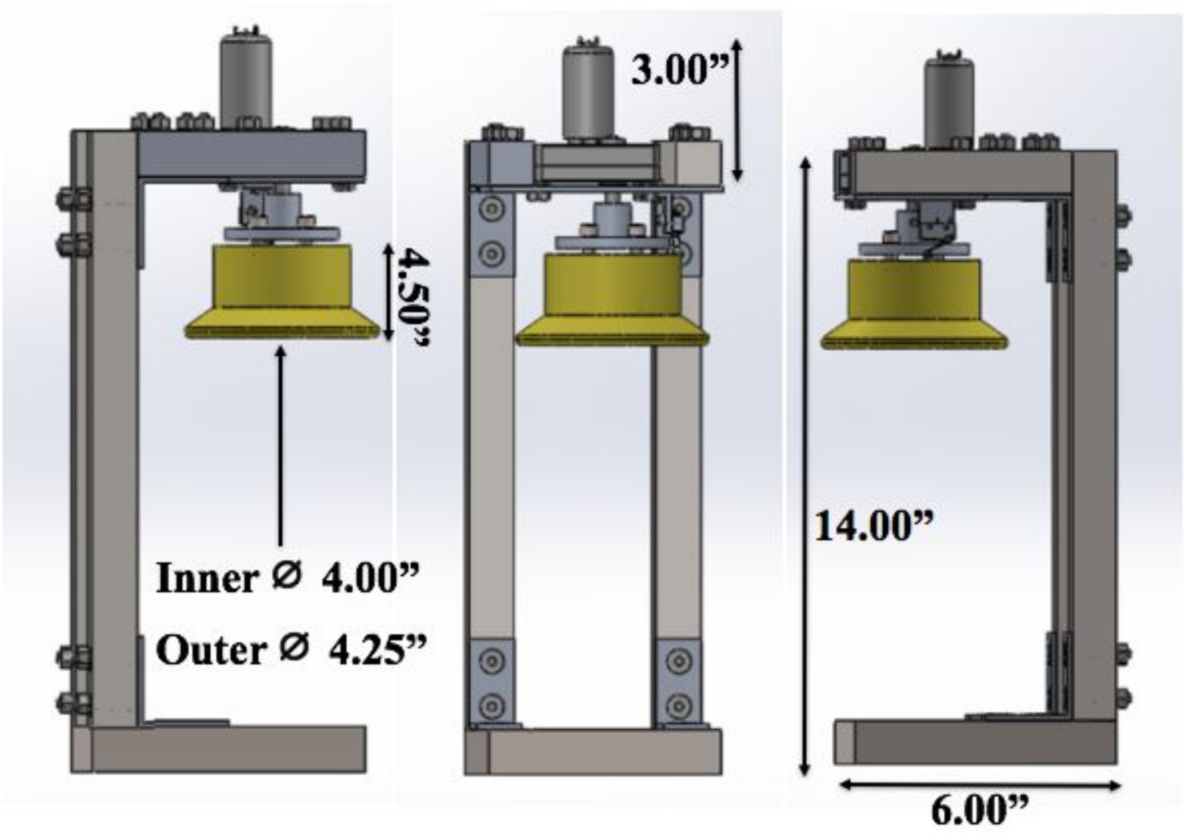


Steel Base Plate



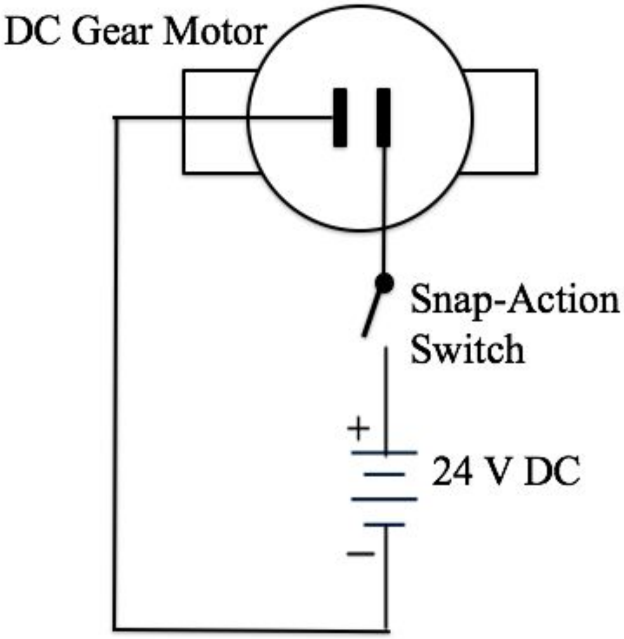
Appendix D

Final Prototype Assembly Drawing



Appendix E

Circuit Schematic



Appendix F

Statistical Analysis

	Workflow Testing: Manually vs With Device (Large)	Workflow Testing: Manually vs With Device (Medium)	Hand Strain Relief Testing: Manually vs With Device (Large)	Hand Strain Relief Testing: Manually vs With Device (Medium)
p-value	0.0264	0.129	0.000048	0.000105
Standard Deviation (s) (manually)	7.70	9.47	0.373	0.471
Standard Deviation (s) (with device)	5.68	8.30	0	0
Variance (manually)	59.3	89.7	0.139	0.222
Variance (with device)	37.6	68.9	0	0

Trial Results

	Container Size: Large (2.19”)	Time (s)	Hand Strain Experienced (0-5)
Trial 1 (Manual)	Large	147	2
Trial 1 (With device)	Large	167	0
Trial 2 (Manual)	Large	132	2
Trial 2 (With device)	Large	155	0
Trial 3 (Manual)	Large	140	2
Trial 3 (With device)	Large	154	0
Trial 4 (Manual)	Large	157	2
Trial 4 (With device)	Large	171	0
Trial 5 (Manual)	Large	148	3
Trial 5 (With device)	Large	164	0
Trial 6 (Manual)	Large	145	3

Trial 6 (With device)	Large	164	0
	Container Size: Medium (1.74”)	Time (s)	Hand Strain Experienced (0-5)
Trial 1 (Manual)	Medium	138	2
Trial 1 (With device)	Medium	130	0
Trial 2 (Manual)	Medium	117	2
Trial 2 (With device)	Medium	147	0
Trial 3 (Manual)	Medium	118	2
Trial 3 (With device)	Medium	144	0
Trial 4 (Manual)	Medium	131	2
Trial 4 (With device)	Medium	131	0
Trial 5 (Manual)	Medium	134	3
Trial 5 (With device)	Medium	151	0
Trial 6 (Manual)	Medium	142	2
Trial 6 (With device)	Medium	133	0

Graphical Representation of Data