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MAGSEAL Delta Seal Gland Fixturing Device

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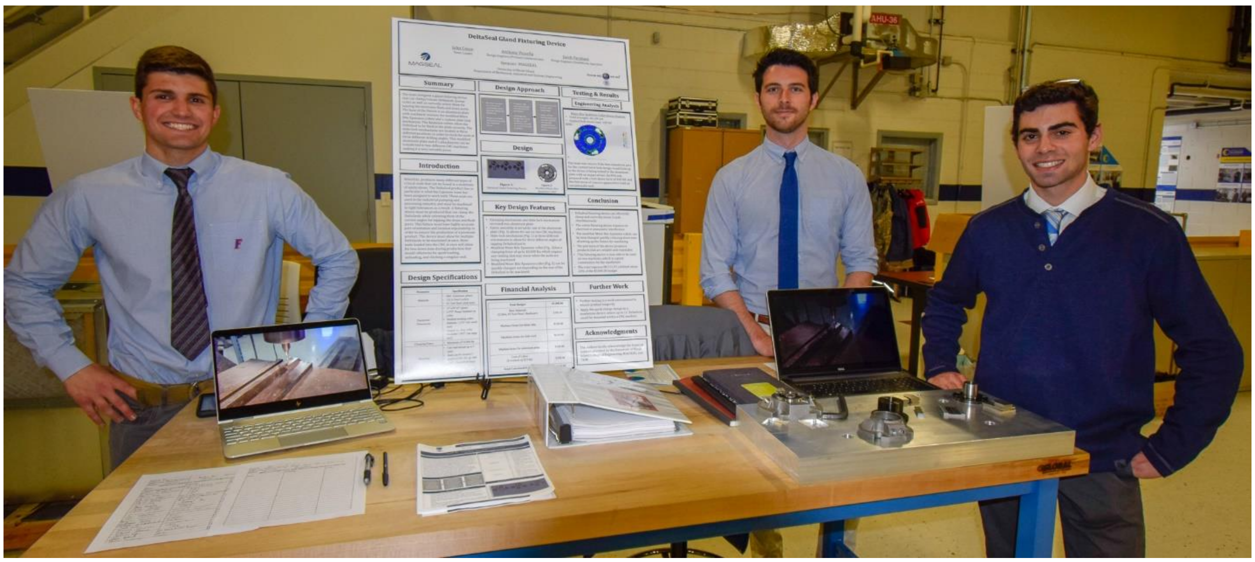
Team 30: “The Dirty Thirty”
MAGSEAL Delta Seal Gland Fixturing Device

MAGSEAL
Maximizing Critical System Reliability



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Engineering Design Report
2018-2019

May 6, 2019

Abstract

This report is an in-depth analysis of Team 30's research and progress pertaining to the assigned capstone project. The scope of the capstone project is to provide the sponsor, MAGSEAL, with a gland fixturing device that can hold at least 3 gland seals within the working confines of the facility's CNC machine. The final iteration will utilize an aluminum base plate with retrofitted designs from Team 30 to fixture the gland seals in a simple manner without the use of electronics or pneumatics. Only simple mechanical actions from a human operator will be used to load and unload gland seals to and from this fixture plate. Throughout the course of the year, Team 30 has performed extensive research and development to formulate designs that will secure these seals to an aluminum base plate fixture. For this project to be successfully executed within the confines of a $5,000.00 budget, Team 30 decided to design a singular mock-up of the base plate to experiment with various securement designs. This aluminum base plate was fabricated from a 2" thick slab of aluminum which is easy to manipulate and test the team's designs on. With the budget presented, Team 30 has provisions to buy the materials necessary, and ensure the ease of use for the operator as well as the successful integration of the Team's designs into an aluminum base plate. The scope of this report is from when the project was assigned on September 17, 2018 to May 6, 2019. This project has undergone many design changes since the beginning of the year. We believe that we successfully design a product that would satisfy all of the goals presented to Team 30 by MAGSEAL. Although we successfully completed all design work, we unfortunately were not able to completely manufacture the final working product. We are confident that we have provided sufficient materials, drawings, and designs for this product to be fully recreated by MAGSEAL if they so choose.

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List of Acronyms

AV – Anthony Vessella (Team 30 member)

JC – John Cocce (Team 30 member)

JF – Jacob Farnham (Team 30 member)

CNC – Computer Numeric Controlled

ID – Inner diameter

J-Loc – A 5C ID collet with an expandable head upon being threaded into a fitting

NPT – National Pipe Thread

OD – Outside diameter

R&D – Research and Development

THM – Technical Hardfacing & Machining (subsidiary of MAGSEAL located in Attelboro, MA)

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1. Introduction

On September 17th, 2018, Team 30 was assigned with the task of designing a way of fixturing multiple MAGSEAL's Delta Seal gland within a CNC machine. These particular seals are gland seals, which are used in the food industry and have flush and drain ports to clean residual material from the inside of seal in order to adhere to health and safety standards. MAGSEAL's subsidiary THM has been tasked with the precision machining of these seals. THM is a machine shop located in Attleboro MA, and was acquired by MAGSEAL earlier in 2018. Together, this deal has presented THM with a higher demand for precision machined parts, and MAGSEAL with another facility to produce more units with close proximity to the company's headquarters in Warren, RI. Currently, THM individually fixes each gland inside the machine, and can only have one seal in the machine at a time. They proposed to URI Capstone to devise a way to fixture 10 or more of these gland seals inside the Kitamura MyCenter HY-400 that is currently used to machine these seals. Upon touring the facility, Team 30 took preliminary measurements to establish design boundaries for machining range and physical parameters. Some of these include the size of the table this fixturing device must reside on and the maximum height the machine can work at effectively. The sponsors at THM and MAGSEAL strongly suggest that Team 30 uses a tombstone to hold the gland seals inside the machine.

A tombstone is a device used by machinists to hold multiple work pieces within the machining center. Tombstones are available in many geometries and sizes depending on what best suits the application. The function of the tombstone in the MyCenter HY-400 machine will be similar to a common spice rack. This machine has a power rotary table for adjusting the angle of the workpieces with respect to the drill, and for selecting different sides of the tombstone to rotate which workpieces are being machined. Team 30's tombstone of choice is a rectangular prism with four equal machining faces, a base designed to secure to the rotary table, and a top with an eyelet for easy removal with a shop crane.

The tombstone must fixture 10 or more seals within these confines: 16"x16" base and under 25" tall from the base to the highest machined feature on the seal. The seals themselves have 3/8 NPT flush and drain holes that must be bored on the outside of the seal and have burrs on the inside that must be smoothed and massaged by the machine. This means that the seals must able to be machined and fixed from both the front and rear to perform the necessary work to finish the product. At the center of this design is operator ease of use, THM sponsor Denis Cotnoir emphasized the simplicity of the final design. He request that the final product be virtually bulletproof in simplicity and utilizes basic movements, no electronic or pneumatic integration with the CNC machine.

To secure these gland seals to the tombstone, an expanding ID gripper or collet is required. For a proof of concept, a pipe stopper is utilized. A pipe stopper consists of two converging cones with an expanding rubber ring in the middle. When the pass through bolt is tightened, the rubber ring expands and secures the gland seal to the tombstone. While this design is primitive in nature it proves the use of an expanding ID device. Dowels are utilized for the correct clocking of the seal for an optimized drill approach.

When executed properly, Team 30's designs will boost the profitability of the Delta Seal for MAGSEAL. This means the machine run time will be increased, and time spent positioning the gland seals will be decreased. Team 30 has done an analysis on the optimal amount of glands within the machine to create the most profit in the financial analysis section of the report.

In addition to decreasing costs and increasing profitability, Team 30 strives to simplify the machinists experience with fixturing the gland seals in order to improve productivity.

Team 30 is a diverse unit of skill sets. Jake Farnham is from Etna, New Hampshire and has experience with laser cutters and advanced Solidworks skills. Anthony Vessella is from Coventry, Rhode Island, and has extensive experience with heat transfer problems and is skilled with AutoCAD. His garage is the epicenter of any fabrication of designs. John Cocce is from Wayland, Massachusetts, and has been exposed to CNC machining and equipment. He has a lengthy experience with mechanical systems as well. Together Team 30 strives to deliver the best possible solution within the parameters presented by MAGSEAL and THM.

2. Patent Searches

Performing a patent search is an integral part in the research stage of any new product design. It is important to understand what other similar products already exist on the market as to not copy or infringe upon any existing patents with the potential new product. If no patent search is done then time and resources could be spent creating a product that already exists which would be an overall waste. Not only would it be a waste of time and resources but it could also produce legal repercussions. A patent search allows the creators to also see any downsides of any product and where they are lacking. This is just as valuable as researching new designs and functional ideas. Once a new and original product has been created, a patent search is also good way of understand where the niche markets are and where new products and further improvements can be created. Since Team 30's product is a one-off product for MAGSEAL, a patent search is necessary more so for concept generation.

Below are patents that are relevant to our capstone design project:

United States Patent 7,210,212

Lin May 1, 2007

Bayonet collet pickup tool for agile fixturing

Abstract

A bayonet collet pickup tool includes a collet chuck having a collet portion including a bore disposed therein. A collet is held in the bore and is operable therein. A bayonet cap is mounted to an outer surface of the collet chuck proximate the bore. The bayonet cap includes a tubular socket concentric with the bore, at least one pair of diametrically opposed linear slots adjacent the socket, and a circular ledge adjacent the socket and perpendicular to the slots. A part including a shaft and at least one pair of diametrically opposed pins projecting from the shaft is receivable in the bayonet cap and the bore. Rotating the collet chuck while the pins are level with the ledge and then closing the collet releasably retains the part in the tool.

Relevance

While researching ways of fixing a Delta Seal gland to a tombstone device, the idea of a quick change receiver was discussed. A quick change feature would greatly decrease the setup time for machinists at MAGSEAL further increasing the number of glands that could be produced. A quick change receiver would be a simpler process which is one of Team 30's objectives.

United States Patent	**7,549,953**
Walters	**June 23, 2009**

Quick change tool holder

Abstract

A quick-change tool-holding method and system for securing a tool within a primary tapered recess is disclosed. The tool-holding system includes an adaptor having a tapered exterior that closely approximates interior dimensions of the tapered recess to fit snugly within the tapered recess. The adaptor defines a secondary interior tapered recess and includes an exterior threaded portion about an aperture leading into the secondary tapered recess. A threaded fastener is also provided to include a threaded portion that is cooperable with threads provided adjacent to the primary tapered recess to secure the adaptor therein, as well as an aperture through which at least a portion of the exterior threaded portion of the adaptor extends when the adaptor is secured within the primary tapered recess by the threaded fastener. A collet comprising a plurality of slits formed therein is provided to allow the collet to elastically deform and constrict the tool when placed within an internal passage defined by the collet. An end cap with threads that are cooperable with the exterior threaded portion of the adaptor is included to urge the collet into the secondary tapered recess resulting in a constricting force on the tool within the collet's internal passage.

Relevance

Along the same lines as the previous patent, a quick change interface would allow a gland to be fixed onto the face of a tombstone device in minimal motions. As previously stated, this would expedite the machining process by reducing the setup time for the operator. This, in turn, would increase productivity and efficiency.

United States Patent	**9,663,304**
Mantell , et al.	**May 30, 2017**

Rotary chuck

Abstract

A rotary chuck includes a clamp assembly, a first drive mechanism for operating the clamp assembly to clamp an associated workpiece, a frame rotationally fixed to the clamp assembly, and a second drive mechanism for rotating the frame and the clamp assembly. The second drive mechanism can rotate the frame and the clamp assembly around 360 degrees. A pair of alignment springs are engaged with a mounting plate upon which the second drive mechanism is mounted. The mounting plate can pivot relative to a stable surface to which it is mounted, and the springs limit the pivotal movement. Each first and second drive mechanism includes a motor, and are connected to a microprocessor for operation of the respective motor.

Relevance

Although electronic devices are not within the objective parameters for this project, the idea of the fixed but rotating clamp is attractive to Team 30. Being able to clamp a Delta Seal gland to the face of this device leaving it rotate would satisfy two of the objectives of this project: to rotate the gland to drill angled holes and to fix, potentially, multiple glands to a face.

United States Patent 10,016,864

McMillan , et al. July 10, 2018

System and method of securing a component in position for machining using a fixture assembly

Abstract

A fixture assembly is configured to securely retain a component, such as an acoustic inlet barrel. The fixture assembly includes at least one component-securing sub-assembly configured to be selectively positioned between a retracted position and a securing position. The component-securing sub-assembly securely retains the component in the securing position, and includes a plurality of component-securing members having outer gripping members that are configured to securely about into an interior surface of the component in the securing position.

Relevance

This is a good representation of the problem definition. The objective is to securely fix a component for machining. The example given is also similar to securely fixing a gland. Team 30 believes that securing the gland from the inner diameter is the most efficient way of securing the gland. Whether is a rubber stopper or a 5C collet, clamping the gland from the inside is the best way of securing the gland, rather than hooking or clamping from the outside.

United States Patent 10,131,023

Werner, Jr. , et al. November 20, 2018

Adjustable fixture

Abstract

The described embodiments relate to adjustable fixtures. A number of adjustable length cylindrical pins can be utilized to form a conformal support structure in accordance with a workpiece having any number of variations. At least three fixed length pins having heights lower than the adjustable length pins, can be interspersed with the adjustable length cylindrical pins to define an orientation at which the workpiece is held. Because the adjustable length pins have an uncompressed height greater than the fixed length pins, each of the adjustable length pins can be compressed in accordance with a bottom surface of the workpiece when the workpiece is pressed against the fixed length pin. In this way a conformal support structure can be formed that supports the workpiece during a machining operation.

Relevance

This is very relevant to Team 30 because the Delta Seal glands have holes that need drilling at odd angles. To fix the glands in the proper orientation, small pins will be fitted in between the “ears” of the glands in different positions radially from the concentric axis. This will allow the machine to drill these holes perpendicularly. Having specific holes drilled into the face of the tombstone will allow the operator to locate the gland for the specific orientations quickly.

United States Patent 6,533,292

Fant March 18, 2003

Pull-to-close collet chuck

Abstract

A pull-to-close collet chuck for use with lathes equipped with servo-type bar loaders. The chuck is configured to be coupled to a lathe drawtube and translates linear movement of the drawtube to a work-gripping action to a collet. The chuck generally includes a ramp body surrounding a first portion of the collet and integral means for fixing the ramp body within a central bore of the chuck. A piston surrounds the collet and has a bearing surface adjacent a ramp surface of the ramp body, and a wedge is located between the ramp surface of the ramp body and the bearing surface of the piston. The wedge has multiple bearing surfaces through which the work gripping action is transferred from the piston to the collet as a result of radial inward movement of the wedge.

Relevance

This is relevant to Team 30 because a simple motion, like pulling, to lock in a collet holding a Delta Seal gland is precisely what the MAGSEAL sponsors had in mind; one motion to fix the glands to the face of the tombstone. This idea combines many of Team 30's design ideas: to use an inner diameter clamping device, to require minimal motions to fixture the gland, and to simplify the setup process for the operator.

3. Evaluation of the Competition

The Delta Seal gland fixturing device that MAGSEAL asked Capstone Team 30 to produce is a custom design tailored to mount and orient their Delta Seal product line. Because the Delta Seal glands are a trademark of the customer, the fixturing device is not compatible with any other type of seal on the market. Therefore, the gland fixturing device that the team produced would not be a product that is able to be sold commercially.

In order to gain a market advantage, Capstone Team 30 cut the cost of production to a bare minimum. The team had to work with a $5,000.00 budget, and only used $502.01, which means that about 10% of the provided budget was spent. The largest way in which cost was cut was through the abandonment of the tombstone. This was a critical demand of MAGSEAL due to the decline in demand for the Delta Seal glands and allowed the team to cut $2,200.00 from the overall expense of materials. The team also tried to select parts that are sold as off-the-shelf products. This is because custom-machined parts can be extremely expensive to replace when labor is factored into the cost of production. The Mitee Bite ID Xpansion collet solved this issue, with each unit being $118.25 per unit. The part number used is 31350, which is applicable for both the smaller and larger sized gland seals. This allows for ease of replacement and there is now no varying cost between the equipment needed to mount and release the smaller and larger sized gland seals.

4. Specification Definition

The customer came forward to Capstone Team 30 with the problem of creating a mechanism that can be analyzed in two different respects. The first portion of the problem that the team was tasked with is the development of a machine that can clamp pump seals, known as Delta Seal glands, for machining. The latter portion of this assignment is to develop a mechanism that can orient the Delta Seals at different angles of offset for angled drilling.

The original Customer Requirements tasked the team with Capstone Team 30 to develop a device that could clamp and orient multiple pump seals simultaneously. This would be done to significantly speed up the machining process so that the production line could keep up with the high demand of these seals. The fixture must hold a minimum of ten Delta Seal glands. There must be between five to ten gland seals oriented for straight drilling. At least five of the gland seals mounted to the fixture must be oriented for angled drilling. The customer also specified that minimal tooling be required, meaning that there is no extensive use of hand tools that are needed to mount, remove, and orient the Delta Seal Glands. This fixture must also require highly accurate part orientation and location repeatability so that every gland seal is machined to the correct tight tolerances.

The Customer Requirements changed towards the end of the course of the fall semester, and by the time that the spring semester began, a new design criterion was provided to Capstone Team 30. The reason for the changes in the Customer Requirements were due to the demand of the Delta Seal Glands being far less than what MAGSEAL has initially anticipated. Because of this decrease in demand, the sponsor wanted to reduce the overall expense of this project as much as possible.

The new Customer Requirements required the team to change up their concepts up to this point. While the customer still wanted a device to fixture and orient the Delta Seal glands, the quantities of how many glands there were to be mounted and oriented was reduced. The first requirement that drastically changed the design was the abandonment of a tombstone fixturing device and the use of a 6061 Aluminum plate that MAGSEAL already had in stock. The use of this plate would reduce the cost of the proposed design by $2200.00. It would also allow for the usage of the mounting and orienting mechanisms to be used in two different CNC machines, whereas only one machine would've been compatible with the previous tombstone fixture. All of the gland seals that were to be mounted to the new fixturing device must be able to be oriented for angled drilling. The customer's original requirements of minimal tooling and highly accurate part orientation and location repeatability remained constant throughout this design change.

Capstone Team 30 turned the Customer Requirements into Engineering Requirements in order to aid in the conceptualization of an efficient and reliable fixture based on the needs of MAGSEAL. The use of the Engineering Requirements led to the formation of design specifications, which are outlined in Table 1. The base plate of the fixture is comprised of 6061 Aluminum with dimensions of 12"x24"x2". This piece is easily machinable and relatively cheap (roughly $500.00 compared to a $2200.00 tombstone) to replace if damaged. The clamping portion of the fixture features a modified Mitee Bite XPansion collet, which is comprised of 12L14 Steel. This material is durable enough to withstand any accidental drops or impacts, yet softer than the material of the Delta Seal glands. This material of the collet is critical to factor in so that when it is tightened down and subsequently expanded, it will not damage the inner diameter (ID) of the gland seals to be machined. The collet is available as an off-the-shelf product which is easily obtainable for additional implementation or for a replacement. The maximum available clamping force that this collet can provide is 10,000 lbs, which is more than enough to prevent the gland seals from moving or rattling due to the vibrations of the CNC drill. The outer flange diameter for these collets is 2.972". The collet part number chosen for this design (Part No. 31350) is compatible with both the smaller sized gland seal (diameter of 1.275") and the larger sized seal (diameter of 1.937"). Knowing these dimensions, the collet can be turned down to 1.272" and 1.924" for the smaller sized gland seal and the larger sized gland seal, respectively. The slide-lock mechanism is the portion of the fixture that will orient the Delta Seal glands at respective angles of 45^o, 55^o, and 100^o depending on where the gland seal needs to be drilled. It is comprised of A2 Tool Steel, which is a very hard metal that will not deform under any circumstances such as vibration or hard impacts such as accidental drops. This slide-lock mechanism is compatible with both small and large sized gland seals, meaning that the customer will no longer have to switch out the fixturing device depending on the size of the gland seal that must be machined.

Table 1: The design specifications of the Delta Seal gland fixturing device that Capstone Team 30 generated can be found below. The table is separated into categories of product materials, equipment dimensions, any necessary force(s) associated with the design, and specifics in mounting of the gland seals.

Parameter	Specification
Materials	• 6061 Aluminum (plate) • 12L14 Steel (collet) • A2 Tool Steel (slide-lock)
Equipment Dimensions	• 12”x24”x2” (plate) • 2.972” flange diameter on collet • Smallest working collet diameter: 1.275” (for small seal) • Largest working collet diameter: 1.937” (for large seal)
Clamping Force	• Maximum of 10,000 lbs
Mounting	• Can load/unload up to 3 seals • Seals can be clocked 3 angles of 45°, 55°, & 100° • Collet diameter for large seal: 1.934” • Collet diameter for small seal: 1.272”

5. Conceptual Design

Concepts Generated by: Anthony Vessella

1. **3-Tooth Jaw Clamp**
   This clamping device would apply friction to the inner diameter of the Delta Seal gland, not allowing any movement or vibration during the drilling process.
   Evaluation: This concept would be ideal if an off-the-shelf unit could be found.

2. **2-Tooth Jaw Clamp**
   This clamping device would apply friction to the inner diameter of the Delta Seal gland. This concept is similar to the 3-Tooth Jaw Clamp, but has one less tooth, which would decrease the cost of material used to produce this clamp.
   Evaluation: It was ruled obsolete as two points of contact on the gland would be insufficient to handle repetitive vibration and drilling.

3. **4 -Tooth Jaw Clamp**
   This clamping device is similar to the 3-Jaw and 2-Jaw clamping device. There are 4 points of frictional contact between the clamp device and the Delta Seal itself.

Evaluation: This clamp would have a greater resistance to vibration but would also cost more because it must be machined in-house, as most off-the-shelf jaws are of the 3-tooth variant.

4. **Thread-on Wing-nut and Washer**
   The inner diameter of the Delta Seal gland will rest on a collar machined to the exact size of the inner diameter of the respective piece is to be machined. In the center of this collar is a threaded rod that will have a washer and wingnut threaded onto it. When tightened, the gland will be compressed to the tombstone to allow for drilling.
   Evaluation: This design would likely fail due to the wingnut backing off due to vibrations.

5. **Adjustable 4-Pin Locking System**
   A Delta Seal gland can be placed on a tombstone, while four dowel pins will grab in between the ears of the gland. At the push of a lever, the dowel pins will retract concentrically, therefore grabbing the seal through the act of "pinching".
   Evaluation: This design was ruled out due to the complexity of the inner mechanics that it would require.

6. **Adjustable 2-Pin Locking System**
   This design is similar to the 4 Pin Locking System previously mentioned but uses two dowel pins that are positioned diagonally.
   Evaluation: This would reduce the complexity of having four dowel pins and only slightly decrease the force of friction that is "pinching" the gland.

7. **Collapsible Grappling Hook with 4 Gripping Claws**
   This concept consists of a grappling hook-like design that goes through the center of the inner diameter of the Delta Seal gland. Four hook-like claws then grab the outer edges of the seal and secure it against the tombstone.
   Evaluation: The complexity of the mechanics and custom parts that would need to be fabricated ruled this design as irrelevant.

8. **Collapsible Grappling Hook with 3 Gripping Claws**
   This design is another iteration of the Collapsible Grappling Hook with 4 Gripping Claws, but only utilizes three claws. The reason for this is to cut down on production cost, as it will be most likely fabricated in-house. The use of three claws also reduces the complexity of the mechanism.
   Evaluation: Like the 4 Gripping Claw concept, the complexity of the mechanics and custom parts that would need to be fabricated ruled this design out.

9. **Collapsible Grappling Hook with 2 Gripping Claws**
   This concept is similar to the two prior grappling hook design but uses only two claws to reduce complexity. The minimal amount of surface contact has made this design less preferable than the 3 or 4 claw iterations.

Evaluation: This design would be complex to produce parts for and the gripping abilities of it would likely not be sufficient enough to negate drilling vibrations.

10. **Four-Faced Tombstone with 2 Mounts per Side**
    This design consists of a pre-built tombstone having 2 mounting places on each face, resulting in 8 total mounting positions.
    Evaluation: It was rendered unusable because MAGSEAL would like at least 10 glands mounted on a fixture at once.

11. **Four-Faced Tombstone with 3 Mounts per Side**
    This tombstone is the most realistic iteration for this particular project. It has 3 mounting positions per side, resulting in 12 total glands that can be machined in one cycle. This surpasses the minimum of 10 and utilizes a commonly found four-faced tombstone fixture.
    Evaluation: This was the ideal base to be used for the project until MAGSEAL voted against paying for it due to lack of Delta Seal demand.

12. **Four-Faced Tombstone with 4 Mounts per Side**
    This iteration is very similar to the two stated above, use the same four-faced base tombstone. It optimizes the quantity of glands that can be fit on a four-faced fixture with the team's current height and width restrictions. It will allow for 16 glands to be machined in one cycle.
    Evaluation: The amount of gland seals mounted on each side would require this tombstone to be too tall and not fit into the Kitamura H400 CNC.

13. **Three-Faced Tombstone with 2 Mounts per Side**
    This tombstone has three faces with 2 mounting places per side, which would allow for 6 glands to be machined at once.
    Evaluation: Although smaller than it's four-faced counterpart, it's mounting capacity is significantly below the minimum number of glands needed to be machined at once.

14. **Three-Faced Tombstone with 3 Mounts per Side**
    This three-faced tombstone has 3 mounting positions per side, which would allow for 9 glands to be mounted at once.
    Evaluation: This design was ruled as obsolete because the sponsor would like 10 glands to be mounted to the fixture.

15. **Three-Faced Tombstone with 4 Mounts per Side**
    This tombstone is similar to the two mentioned previously, using a similar 3-faced base. It would be able to hold 12 glands at once for a machining cycle.
    Evaluation: This design utilizes a tombstone that it unorthodox, and possibly difficult to purchase as an off-the-shelf product.

16. **Five-Faced Tombstone with 2 Mounts per Side**

This tombstone has five faces and would allow for 10 glands to be mounted when at full capacity.
Evaluation: This design was ruled out as obsolete because with the height constraints provided, a tombstone with a similar amount of faces could easily hold more than 10 glands.

17. Five-Faced Tombstone with 3 Mounts per Side
This tombstone has five faces and 3 mounting fixtures per side, allowing for a total number of 15 glands to be machined at once.
surpasses the manufacturer's requirement, which is 10 glands. This product was ruled out because of the cost of the five-sided tombstone, and the glands might possibly hit each other when they are mounted.

18. Five-Faced Tombstone with 4 Mounts per Side
This five-faced tombstone has 4 mounting positions on every face, equating to a total of 20 glands that can be machined at once.
Evaluation: This design would optimize the number of glands that can be placed on a five-faced tombstone, while still remaining within the sponsor's requested height restrictions. This product was ruled out because of the cost of the five-sided tombstone, and the glands would hit each other when they are mounted.

19. Six-Faced Tombstone with 2 Mounts per Side
This tombstone has six faces in total, and 2 mounts per side. It would be able to hold a maximum of 12 glands at one time.
Evaluation: This number surpasses the minimum requirement of glands that must be machined at once, which is 10. The bulkiness of 6 faces with glands on them have ruled this design out.

20. Six-Faced Tombstone with 3 Mounts per Side
This design utilizes a six-faced tombstone with 3 mounting positions on each side. The maximum capacity of glands that this tombstone can withhold is 18.
Evaluation: This does satisfy the condition of having at least 10 glands on a fixture at once, but it's bulkiness would prevent it from being usable.

21. Six-Faced Tombstone with 4 Mounts per Side
This tombstone uses a six-faced base similar to the previous two designs above but allows for a total of 24 glands to be mounted at one time.
Evaluation: This value is over double the minimum of what the sponsor had requested, which was 10. However, like the other six-sided tombstone, this design would most likely be too bulky to fit into the drilling machine.

22. Four-Faced Tombstone with Material Removed

This tombstone is similar to a generic four-faced tombstone but has had material removed to allow for a less bulky design. Anywhere from 2 to 4 mounting fixtures may be placed on this tombstone.
Evaluation: This design was ruled out because it would be very time consuming to remove material on the tombstone itself. It may also compromise its structural integrity.

23. Five-Faced Tombstone with Material Removed
This design features a tombstone with five faces that has had material removed from each face, thus decreasing the overall weight and bulkiness of the finalized product. It would allow for more degrees of freedom when being placed into the machining compartment.
Evaluation: This design was ruled out because it would be very time consuming to remove material on the tombstone itself. It may also compromise its structural integrity. There is still a chance of the gland seals interfering with each other when mounted.

24. Six-Faced Tombstone with Material Removed
This concept is based around a six-faced tombstone that has had material removed, so that it may be possible to fit it inside of the machining compartment. It would optimize the number of glands that can be mounted at once (up to 24), while still abiding by the height constraints.
Evaluation: This design was ruled out because it would be very time consuming to remove material on the tombstone itself. It may also compromise its structural integrity. There is still a chance of the gland seals interfering with each other when mounted.

25. Lever System Allowing Two Mounts to Rotate
This lever mechanism has linkage located behind the tombstone face that would allow for the glands to be rotated while they are mounted. This would allow for angles drilling without having to remove the glands from the tombstone fixture.
Evaluation: The complexity of the linkage involved within the tombstone ruled this part out. The space within a tombstone is quite limited, the four linkages for each side may be fragile and would not hold up the machine shop environment.

26. Lever System Allowing Three Mounts to Rotate
This lever mechanism follows the same principle as the one mentioned above but allows for three glands that are mounted to a tombstone face to be rotated.
Evaluation: This mechanism requires slightly longer linkages, and a result is a bit more complicated than the two-mount rotation device listed above.

27. Lever System Allowing Four Mounts to Rotate
This concept features a lever mechanism that can allow for four glands mounted to a tombstone face to rotate simultaneously.
Evaluation: Due to the complexity of the linkage that would be behind the face of the tombstone, this device has been ruled out.

28. Tombstone with Offset Mounts for Multiple Size Allowances

This principle applies to a four-faced tombstone that has faces with mounts that are only able to hold a certain size gland, whether it be the smaller or the larger of the two. This is done so that multiple small glands can be mounted to one side, thus optimizing the space provided.
Evaluation: This design would eliminate the need for interchangeable mounts for different sized glands as well. It was ruled out because the offset mounts would decrease the total number of gland seals that can be mounted to the surface of each side.

29. Levers Mounted on Every Face for Clamping and Releasing

Rather than utilize one master lever, this design has four separate levers for each face of the tombstone (in this case, a four-face tombstone was used).
Evaluation: This design was ruled out because it would be difficult to implement into a five or six-faced tombstone, however.

30. J-Loc 5C Collet Threaded into Tombstone

This design utilizes a J-Loc 5C Collet that can be machined. These collets can be threaded, and threads can be tapped into the tombstone, where these collets can then be fastened. They offer much more surface area than a standard 3-Tooth Jaw design and are readily available.
Evaluation: This design is the front-runner moving forward and will most likely be used if an off-the-shelf product is available and able to be modified.

Below are figures of the concepts generated by Anthony Vessella.

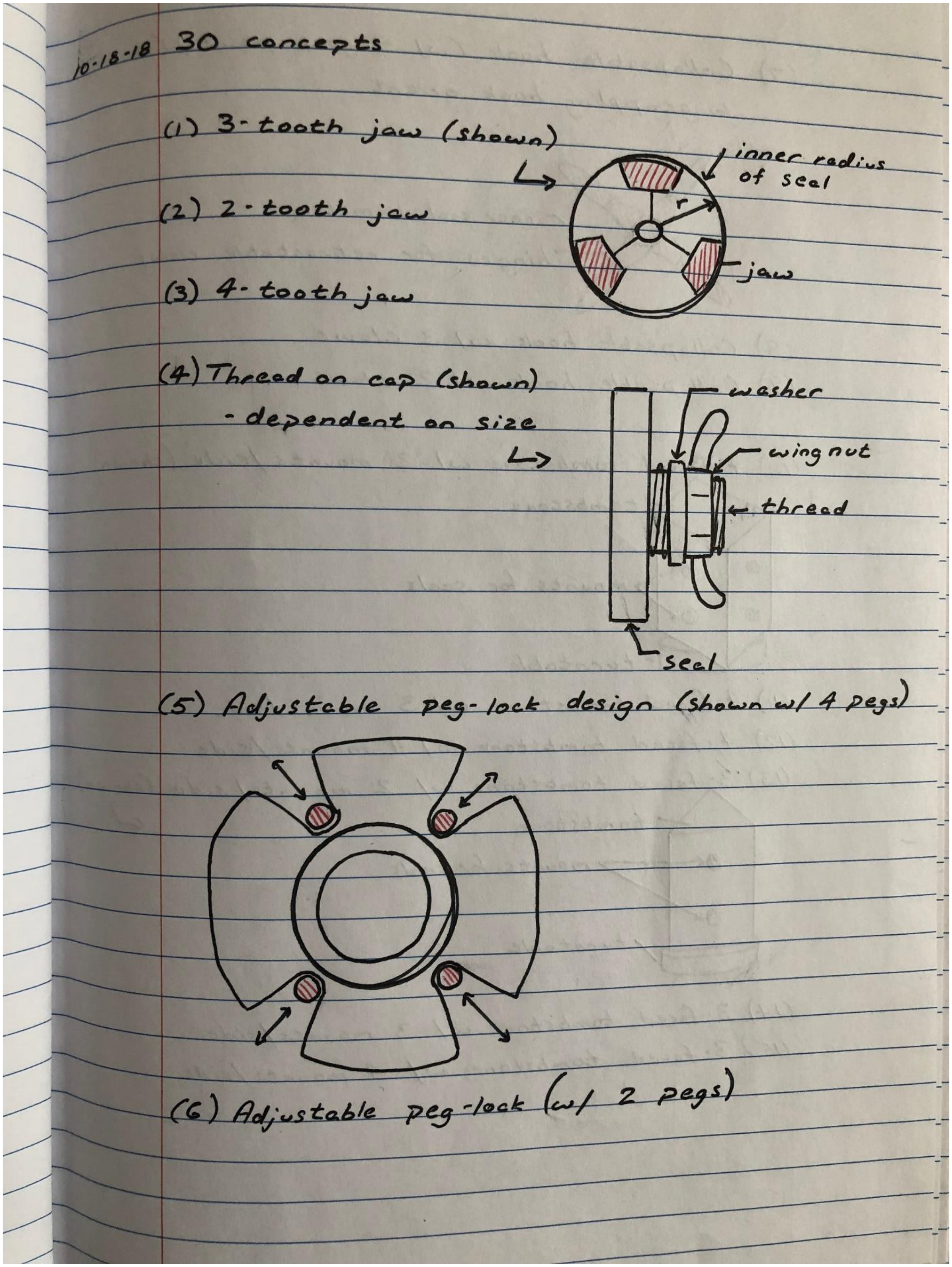


Figure 1: Anthony's concepts 1-6.

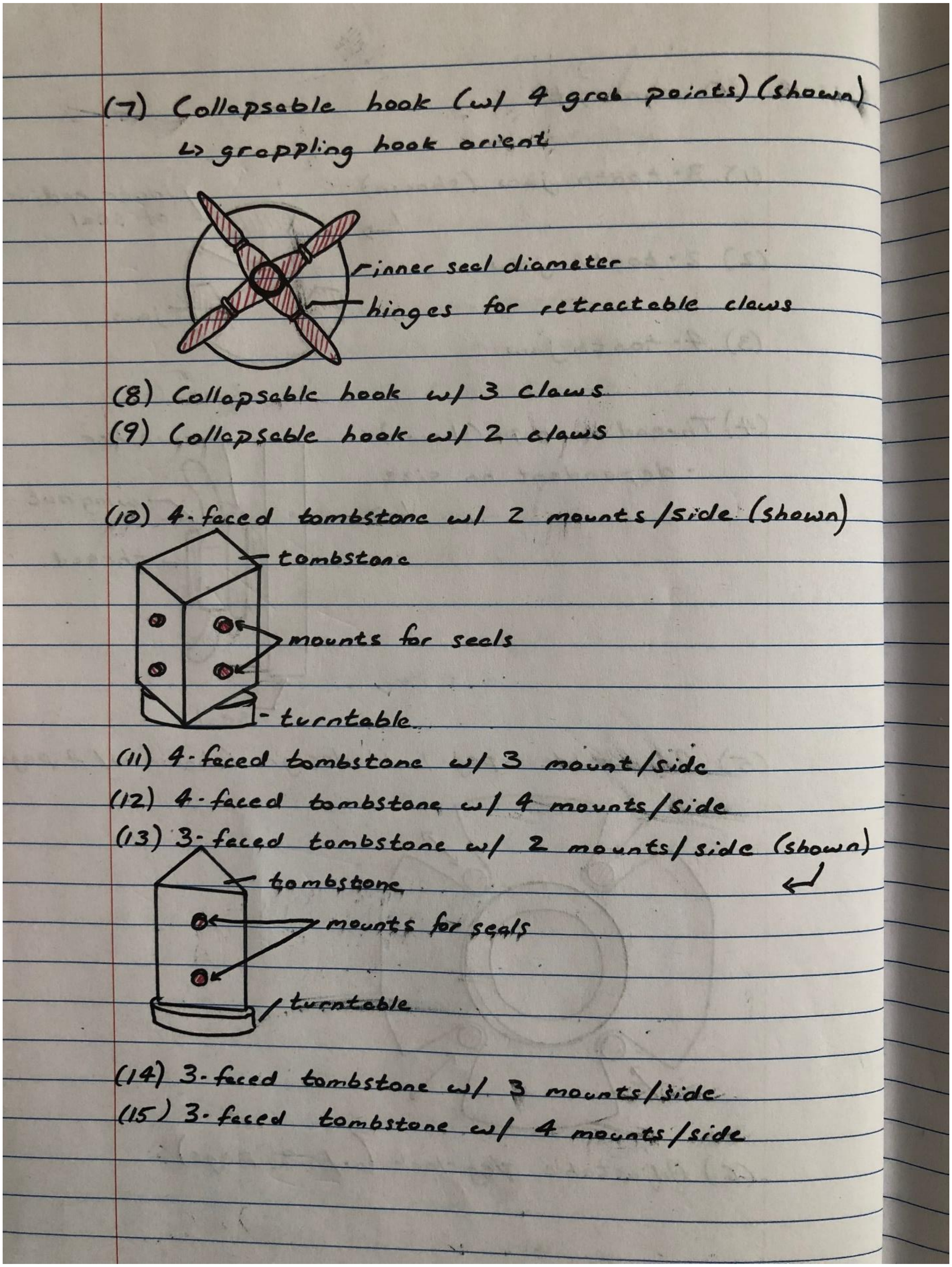


Figure 2: Anthony's concepts 7-15.

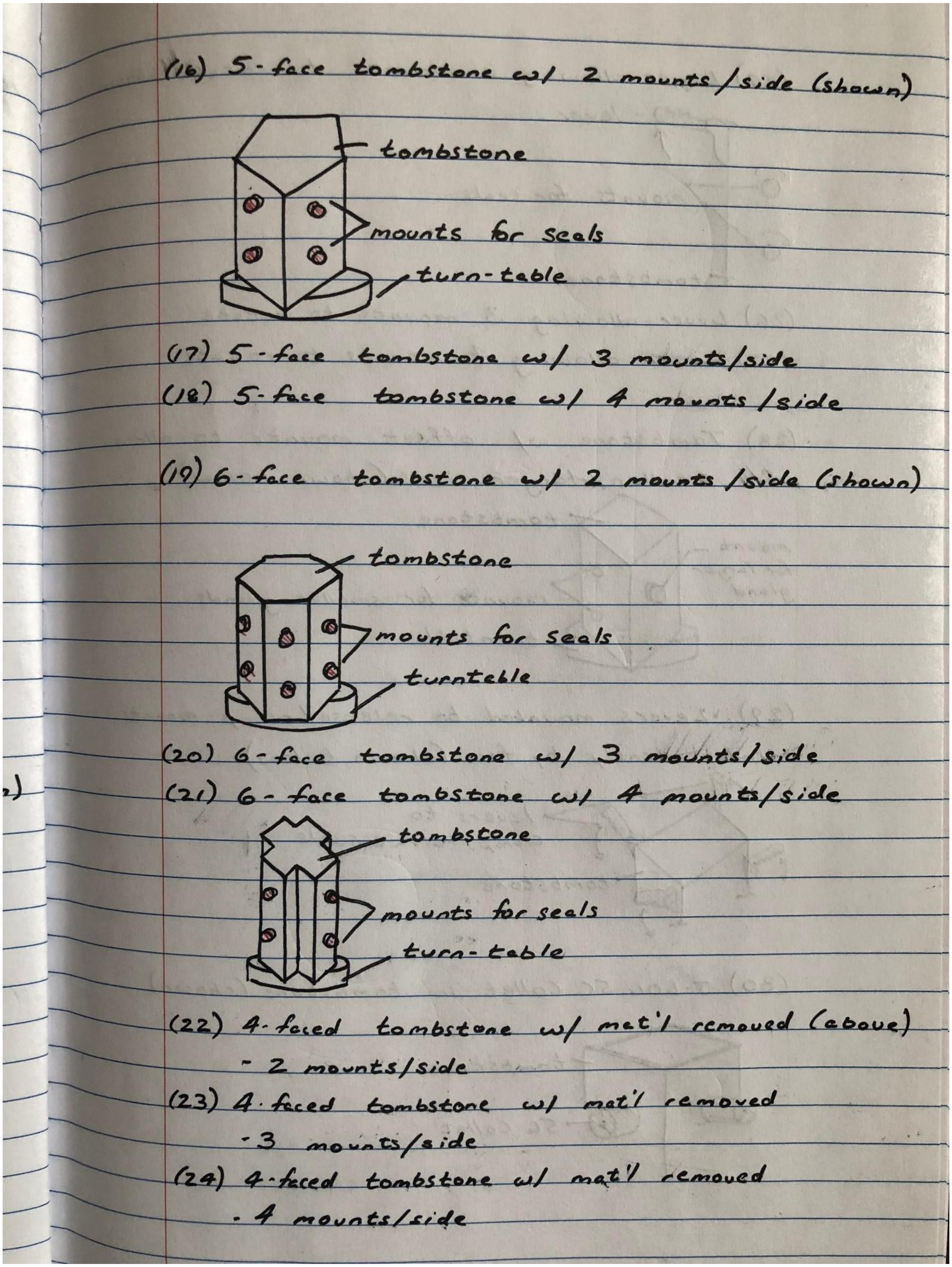


Figure 3: Anthony's concepts 16-24.

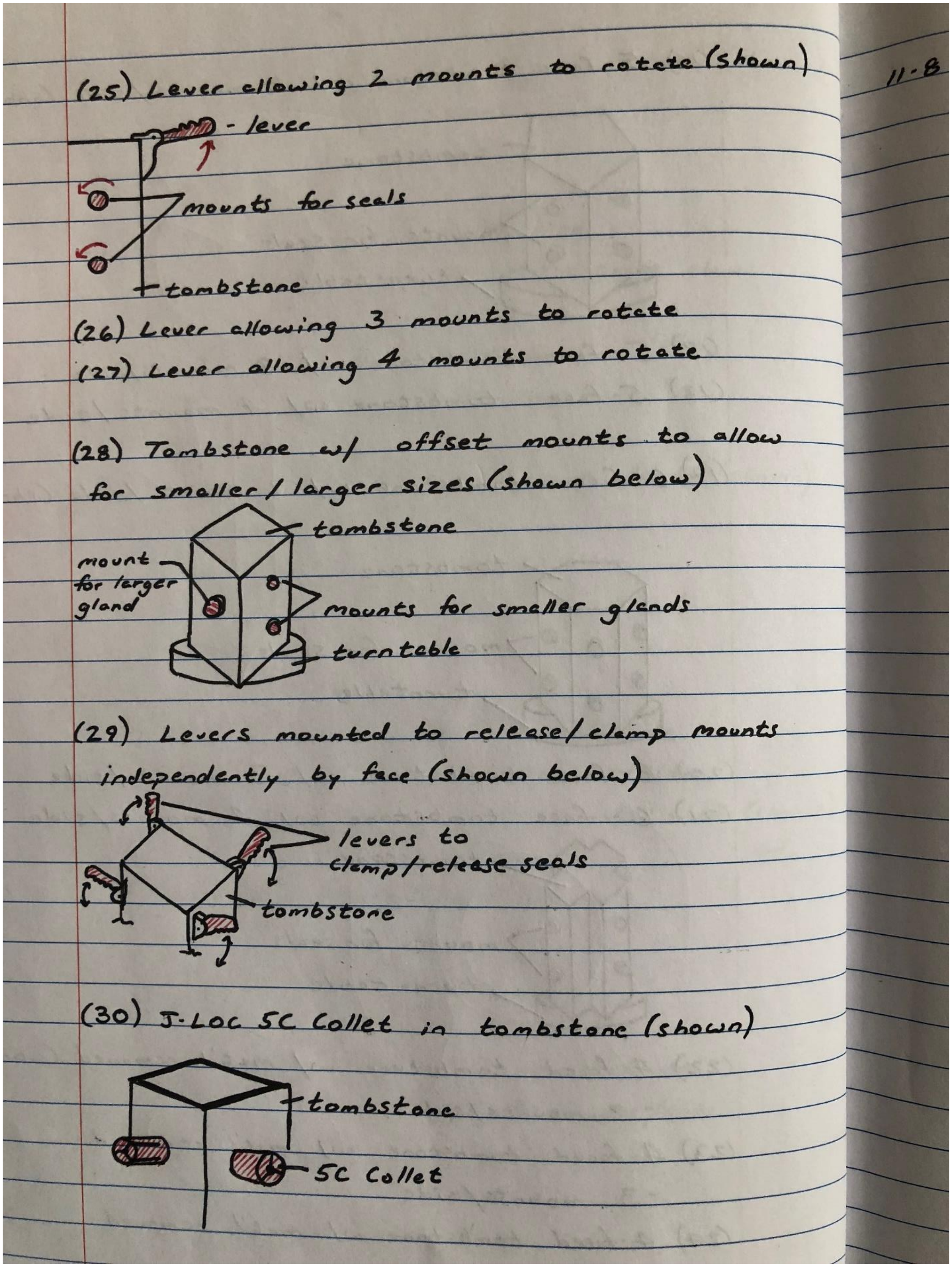


Figure 4: Anthony's concepts 25-30.

		Concepts																													
Engineering Criteria	Reference Concept	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Gland Clamp Designs																															
Performance	S	S	-	S	-	S	S	-	-	-																-	-	S			S
Functions	S	S	S	S	S	S	S	S	S	S																S	S	S			S
Reliability	S	S	-	S	S	S	-	-	-	-																S	S	S			S
Durability	S	S	-	S	S	-	-	-	-	-																-	S	S			S
Conformance	S	S	S	S	-	S	S	S	-	-																S	S	S			S
Perceived Quality	S	S	S	S	S	S	S	-	-	-																S	S	S			S
# of Plusses		0	0	0	0	0	0	0	0	0																					0
# of Minuses		0	3	0	2	1	2	4	5	5																					0
Tombstone Designs																															
Performance	S										-	-	-	-	-	-	-	-	S	-	-	-	-	-	-				+	+	
Functions	S										S	S	S	S	S	S	S	S	S	S	S	S	S	S	S				S	S	
Reliability	S										S	S	S	S	S	S	S	S	S	S	S	S	S	S	S				-	S	
Durability	S										S	S	S	S	S	S	S	S	S	S	S	S	-	-	-				S	S	
Conformance	S										-	-	-	-	-	-	-	-	-	-	S	S	-	S	S				S	S	
Perceived Quality	S										S	S	S	-	-	-	S	S	S	-	-	-	S	S	S				S	S	
# of Plusses											0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1	1	
# of Minuses											2	2	2	3	3	3	2	2	1	3	2	2	3	2	2				1	0	

Figure 5: Pugh Chart of Anthony's 30 concepts.

Concepts Generated by: John Cocce

1. **Lazy Tombstone**
   Dubbed the "Lazy Tombstone" this concept is of a tombstone with a rotating base. It is elementary in nature and deemed unnecessary because the Kitamura MyCenter HY-400 has a rotary table which can adjust the rotation of the tombstone via operator commands.
   <u>Evaluation:</u>
   While this concept would not be necessary for this machine, it would work great on a machine with a fixed table rather than a rotary model.

2. **Single Sliding Dowel**
   A sliding dowel system that fixes the gland by the bolt ears. While nice on paper, it requires a complex system that is best suited by pneumatics which doesn't adhere to our sponsor's requests.
   <u>Evaluation:</u>
   This is locating system is better than the hook concepts for accuracy of locating.

3. **Twist Lock**
   This twist lock system is close in nature to our proof of concept which utilizes a pipe stopper with a wing nut to affix the gland to the mock-up tombstone.
   <u>Evaluation:</u>
   The twist lock is good but it lacks a good way to clock the gland.

4. **Splined Shaft**
   This subsystem idea makes use of a splined shaft that dogs into a gear or pulley to rotate the gland for the proper machining angles.
   <u>Evaluation:</u>
   This is too complicated in nature due to the high amount of moving parts required to make this work.

5. **Cam**
   This concept is of a cam actuated system to pull the gland into the tombstone. While a great idea in nature it is a tough fit for the close confinements of the interior of a tombstone.
   Evaluation:
   Too intricate to fit in the center of a tombstone.

6. **Conical Dowel**
   This conical dowel design is not far off of the operation of the pipe stopper featured in Team 30's proof of concept. While simple in nature and a seemingly good fit, this design if universally implemented across all gland seal sizes would block the machining process of smoothing out the burrs of the flush and drain holes from the ID of the gland.
   Evaluation:
   This idea is good on paper, however it blocks some of the machining required on the backside of the gland.

7. **Screw Dowel**
   Number seven is a slightly different variation of the previous, however it screws into the tombstone instead of using a pass through design that will engage a linkage contrary to the previous design. Team 30 is gravitating toward using a device of this nature that threads into the tombstone rather than stuffing a complicated linkage inside a tombstone.
   Evaluation:
   This concept is obsolete because a tombstone is no longer an option.

8. **Stepped Dowel**
   Yet another variation of the cone design first displayed in concept #6, this one has ribbed detents for the varying inside diameters of different size glands to be machined. This design is being considered with the final product because of the excellent fit it would provide with a shouldered edge to abut the ID of the gland.
   Evaluation:
   Once again, it presents the issue of machining around the ID of the gland when flipped because of the universalness of the design. In a more refined product, each size of seal will have its own shouldered "plug" to fit into the ID.

9. **Rotating Hook**
   This rotating hook was going to be the focus of an inside linkage if Team 30 was to pursue one. When properly implemented, this hook would allow a pass through dowel to be removed and gripping collets to be changed.
   Evaluation:
   This is no longer viable due to the removal of a tombstone from the project.

10. **Vertical Rod**
   Utilizing a vertical rod with hooks in it, this particular concept would require the operator to push down and turn a centrally located rod to disengage the fixturing device from the glands.
   Evaluation:

This concept was deemed too fragile and lacks longevity as the hooked surfaces would wear prematurely due to the high amount of strain they would be required to endure.

11. Spring Loaded Vertical Rod

This concept is the same as the previous in regards to the hooks, however it was noted that a spring-loaded design would keep it in its predetermined detents.

Evaluation:

This concept suffers from the same shortcomings as the previous, but it has good intentions with the implementation of detents which are a necessity for good repeatability of gland gripping.

12. Threaded Vertical Rod

Another idea similar in nature to #10, however this one threads into the base of the tombstone for securement and vertical movement and engagement.

Evaluation:

This concept was deemed obsolete with the removal of a tombstone from the project.

13. Vertical Rod Engagement

Yet another idea that involves a vertical rod, however this one concept focuses on the engagement of a pass through style rod that will pull the gland into the face of the tombstone to be machined.

Evaluation:

This idea lacks in simplicity but has an excellent premise to realistically pull in the gland.

14. Four Sliding Dowel

Concept 14 is based along the sliding dowel system presented in concept 2. The only variation is the use of four dowels to engage the gland.

Evaluation:

This design is also too complex in nature.

15. Two Sliding Dowels

This concept also utilizes sliding dowels similar to concept 14 and 2, but will utilize two dowels and rotates.

Evaluation:

Same issue, still too complicated to integrate on a tombstone.

16. Four Sided Tombstone

A four sided tombstone that holds 8 gland seals, so 2 on each side. Our financial analysis displays that the optimal number of seals fixture within the machine is 10.

Evaluation:

This idea was well liked by our sponsor, however, they decided the best route was to use an existing aluminum plate.

17. Another Four Sided Tombstone

Same as above, only with three glands per side of the tombstone. Slightly above our goal of 10 glands within the machine at once, but this could be used and have two fewer glands fixed than the capacity for the optimal number.
Evaluation:
Same as concept 16.

18. Two Sided Tombstone
A two sided tombstone that fixtures three gland per side, yielding only 6 fixtured gland which is too few.
Evaluation:
Same as concept 16.

19. Another Two Sided Tombstone
Another two sided tombstone that holds two glands per side. Doesn't hold enough gland within the machine.
Evaluation:
Same as concept 16.

20. Six Sided Tombstone
A six sided tombstone that can hold three glands per side yielding 18 fixtured glands within the machine at once, which is 8 too many according to our analysis.
Evaluation:
Our sponsor decided that the single sided aluminum plate would be the best course of action.

21. Another Six Sided Tombstone
Another six sided tombstone that can hold 12 glands within the machine at a time. This design is good but the cost of tombstones can be minimalized with the use of a blank four sided tombstone.
Evaluation:
Same as concept 20.

22. Four Hooks ID
This concept utilizes a system of four hooks to secure the gland seal to the tombstone. Another idea that is too complicated to integrate to the standards requested by our sponsors.
Evaluation:
This idea is too complicated to implement at a respectable cost.

23. Two Hooks ID
Same design as the previous with the same issues, only this one utilizes two hooks instead of four.
Evaluation:
Same as concept 22.

24. Eight Sided Tombstone

An eight sided tombstone with two glands per side, after visiting the sponsor facility at THM, this is impossible due to geometrical constraints.

Evaluation:

Same as concept 20.

25. ID Gripper

This system has good intentions of a way of gripping the gland from the ID, however the hooks would be best utilized by a Schunk-style expanding gripper.

Evaluation:

The Schunk style gripper is too expensive for our project and requires pneumatic integration.

26. Three Hook System

Same as the previous, uses three hooks instead of four.

Evaluation:

Also too complicated to implement on our project.

27. Two Hook System

Same as the previous, uses two hooks instead of three.

Evaluation:

Same as concept 26.

28. Robot Arm

An integrated robot arm would be very nice, but it is way out of the $5,000 budget presented by our sponsors.

Evaluation:

Too expensive for our project.

29. Visual Inspector

A visual inspection system would be nice for quality assurance, the team may utilize one if there is a sizeable amount left over in the budget, maybe from a company like Cognex.

Evaluation:

Too expensive for our project.

30. Conveyor Belt

A conveyor belt to feed the robot arm is also out of the budget.

Evaluation:

Not necessary for the successful implementation of our project.

Below are figures of the concepts generated by John Cocce.

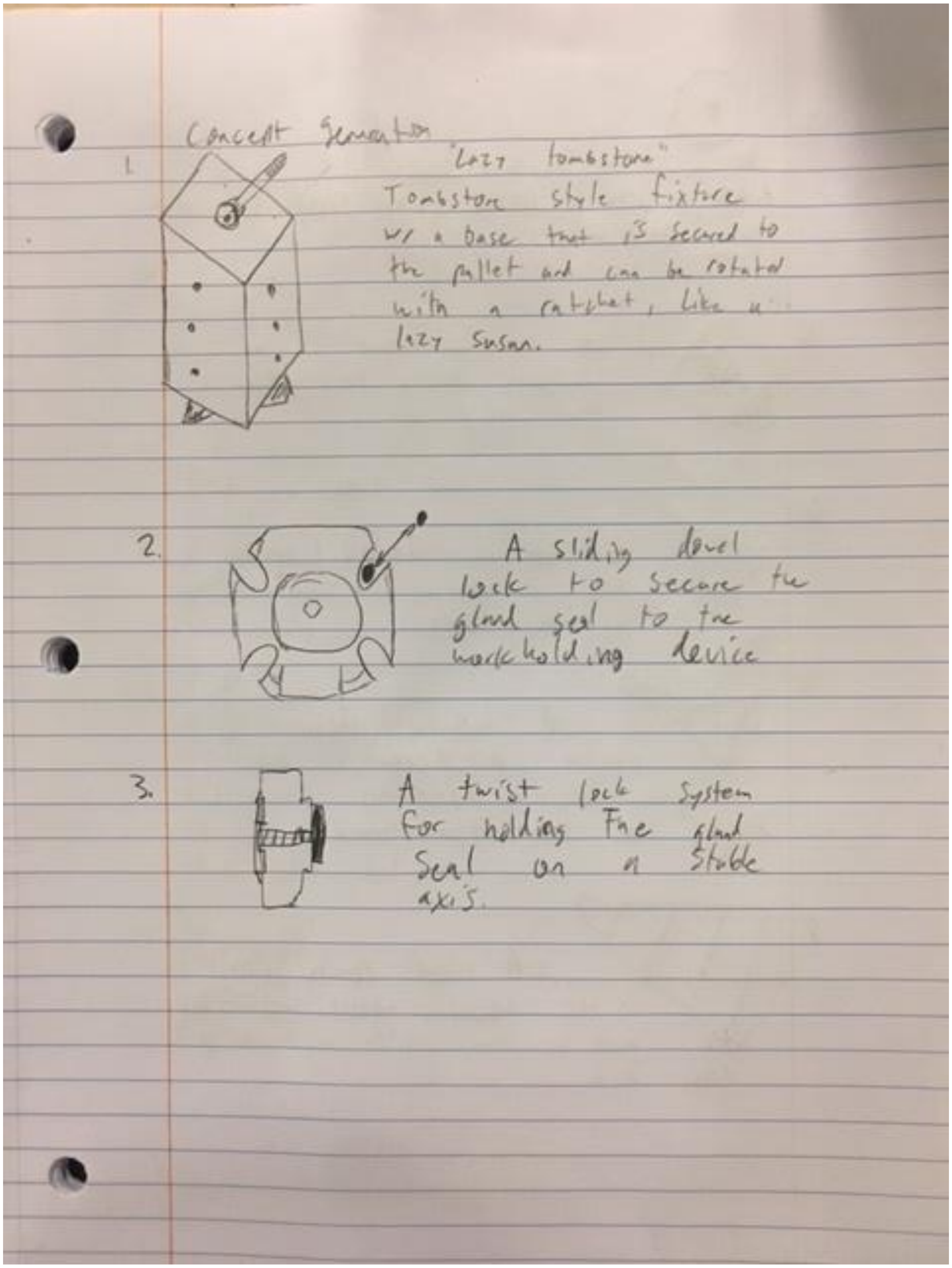


Figure 6: John's concepts 1-3.

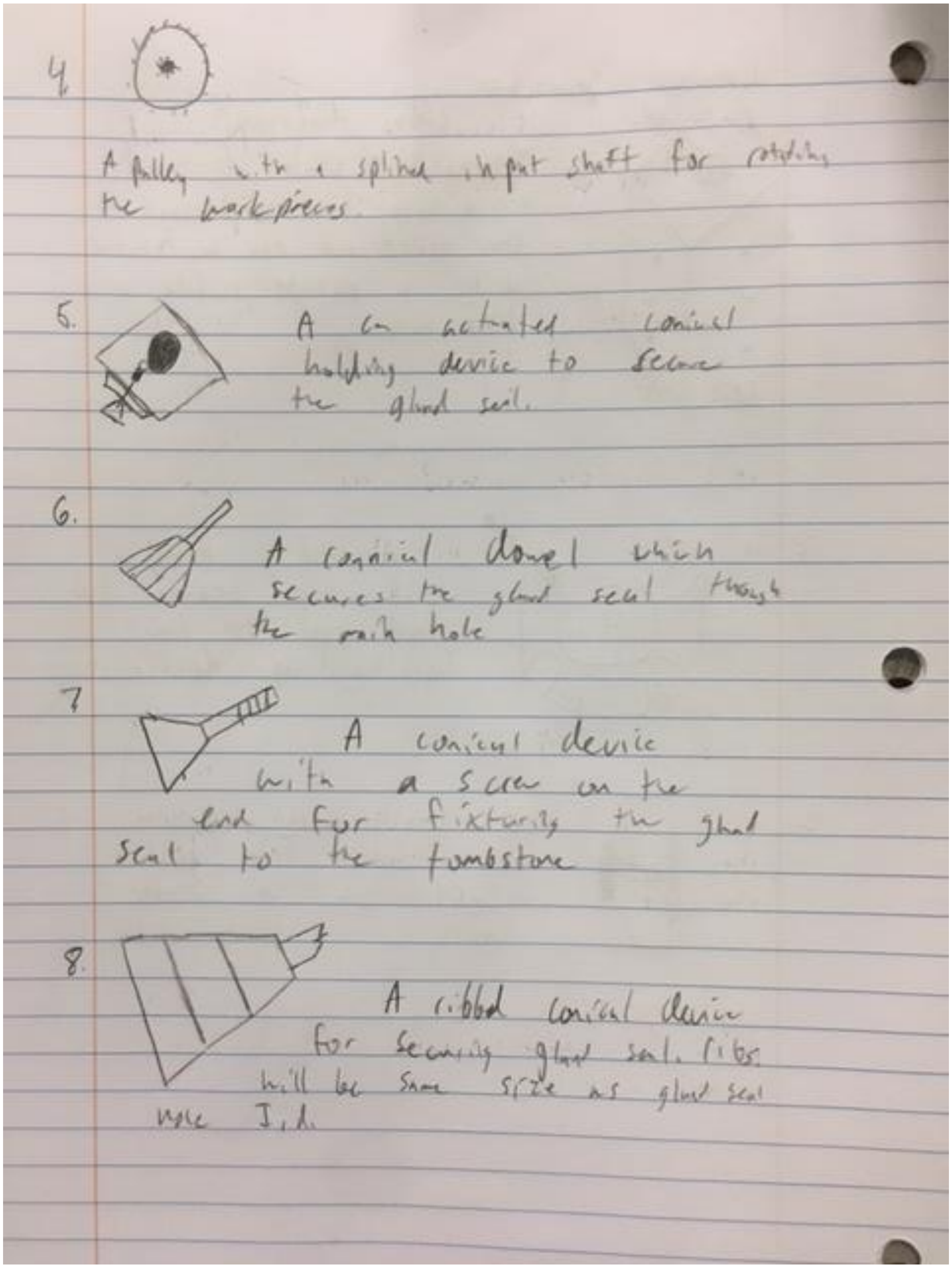


Figure 7: John's concepts 4-8.

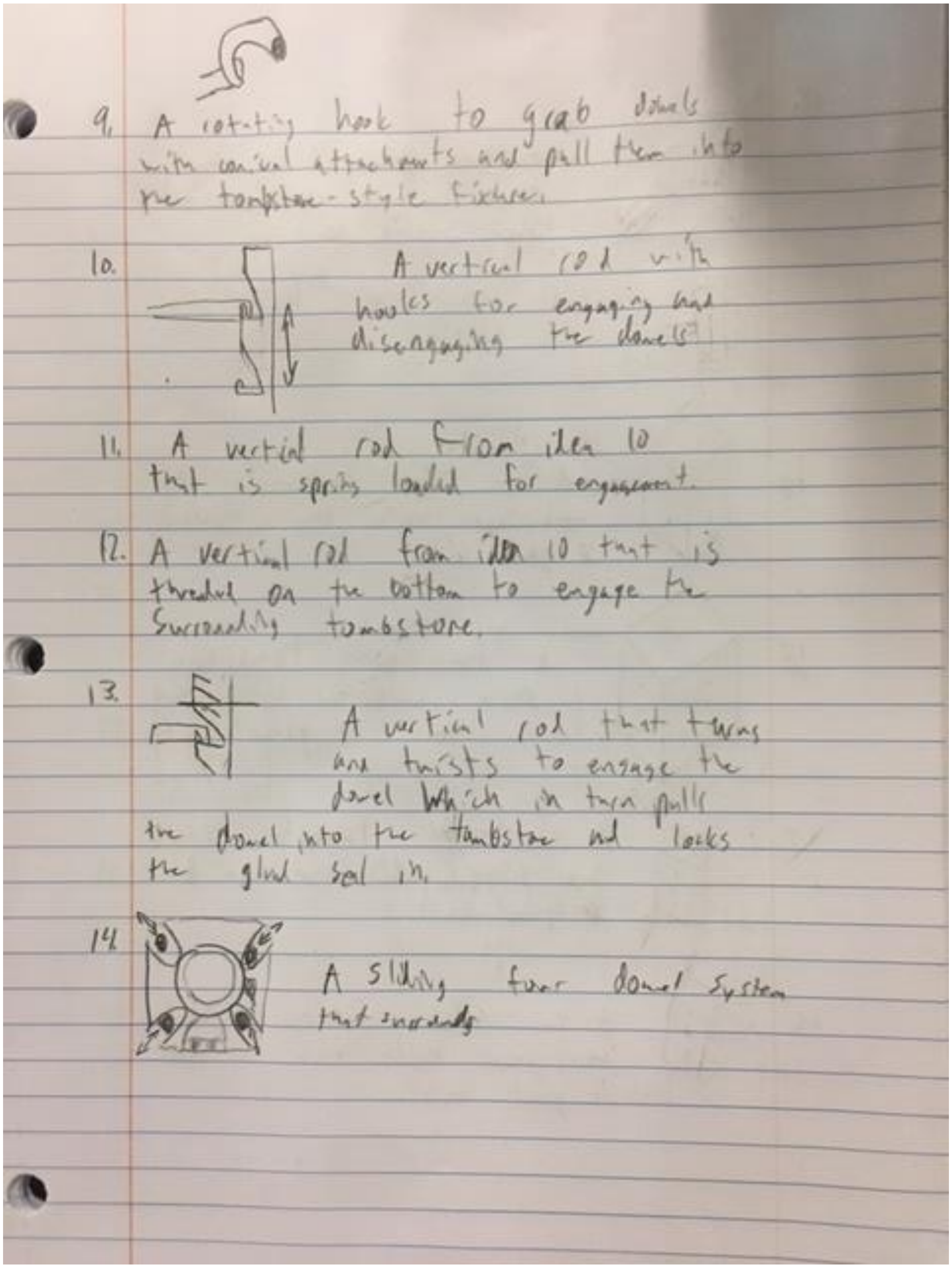


Figure 8: John's concepts 9-14.

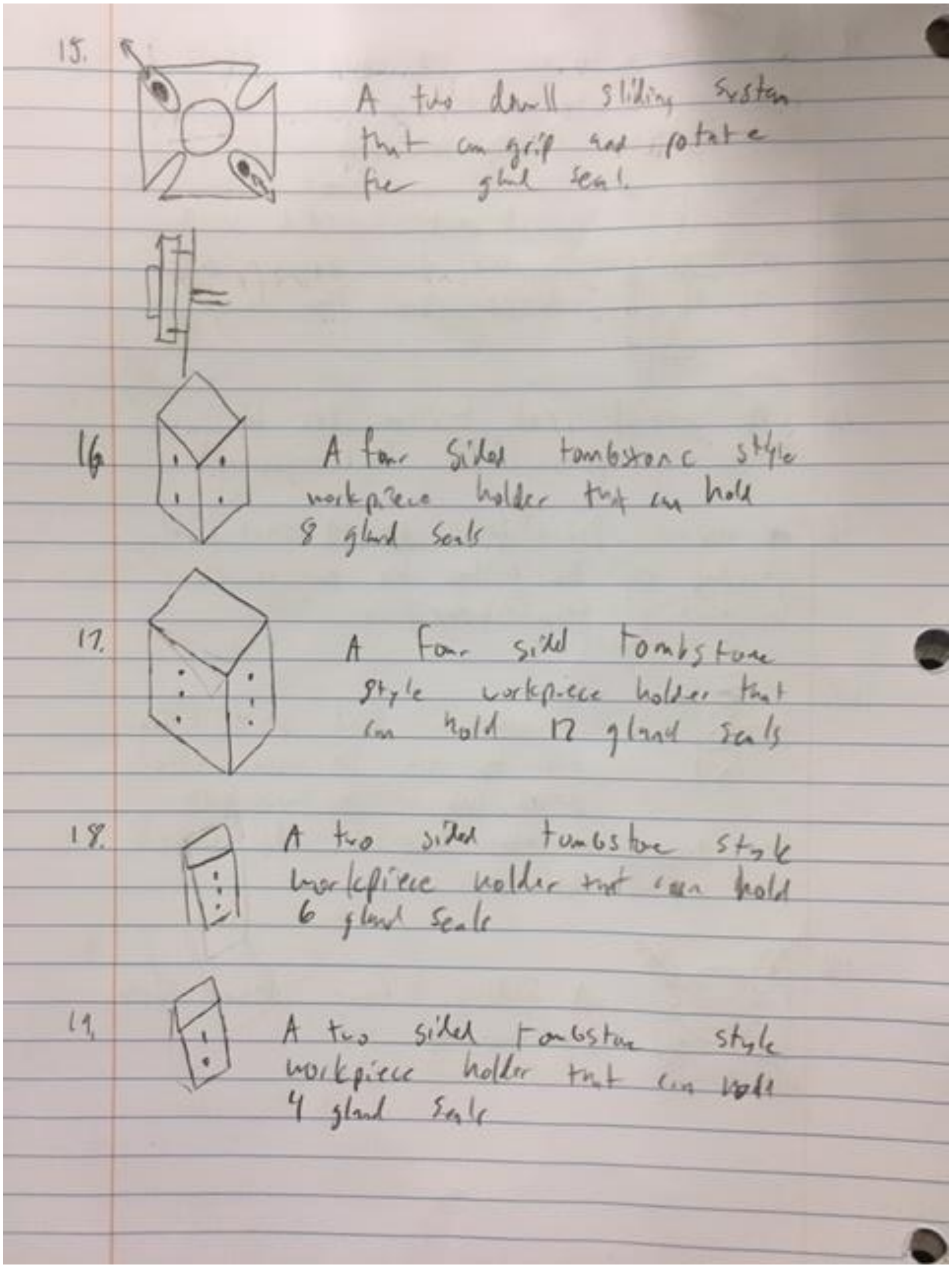


Figure 9: John's concepts 15-19.

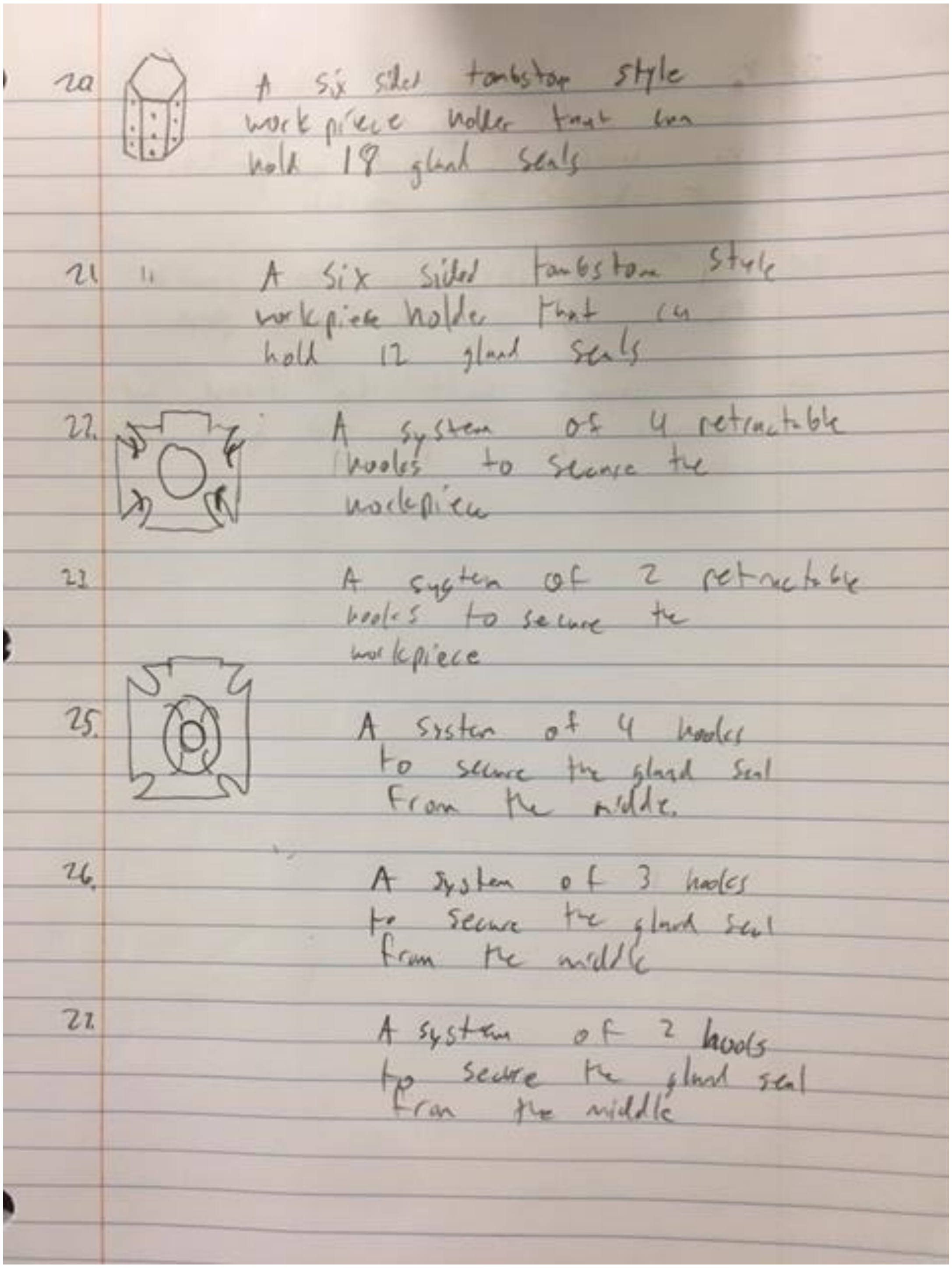
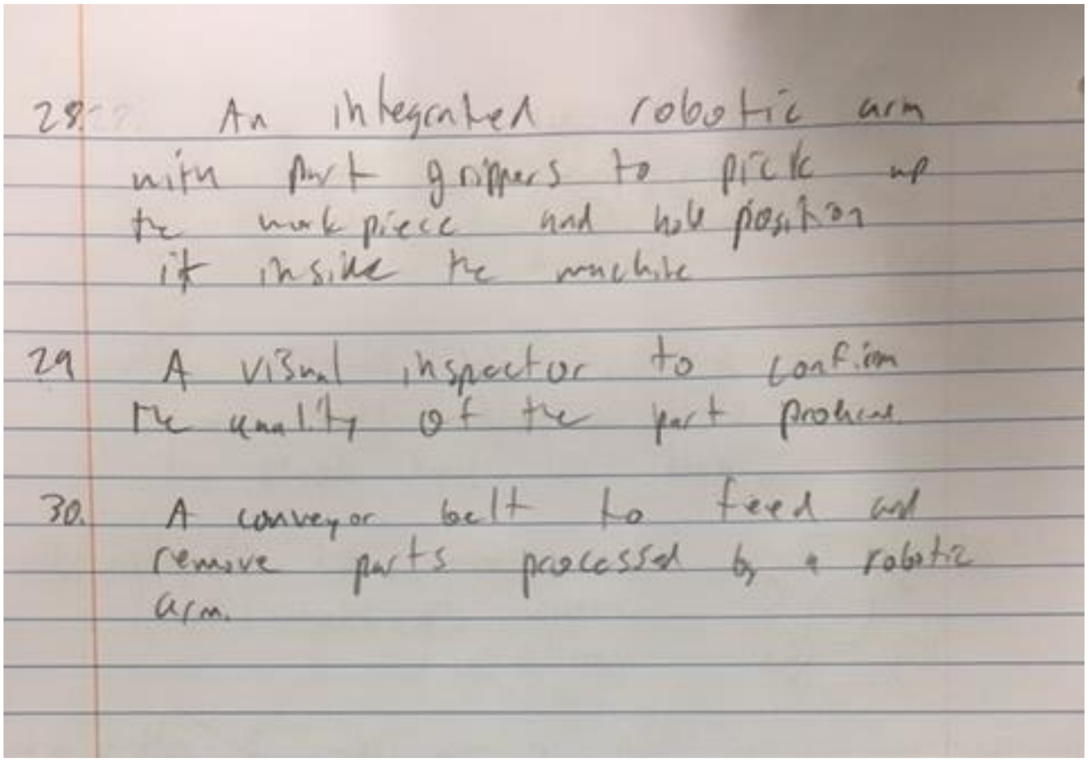


Figure 10: John's concepts 20-27.



28. An integrated robotic arm with part grippers to pick up the work piece and hold position it inside the machine

29 A visual inspector to confirm the quality of the part produced.

30. A conveyor belt to feed and remove parts processed by a robotic arm.

Figure 11: John's concepts 28-30.

		Concepts																													
Engineering Criteria	Reference Concept	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ease of Use	1	+															-	-	-	-	-	-									
Simplicity	1	-															+	+	+	+	-	-									
Durability	1	+															+	+	+	+	+	+									
Moving parts	2		-												-	+							-	+	-	-	+	-	-	+	-
User interaction	2		+												+	+							+	+	+	+	-	+	+	+	+
Economic	2		-												-	-							+	+	+	+	+	-	-	-	-
Ease of Use	3			+	+	+	+	-	+	+	+	+	+	+																	
Serviceability	3			+	+	+	+	+	+	+	+	-	+	+																	
Durability	3			+	-	-	+	-	+	-	-	-	-	-																	
# of Plusses		2	1	3	2	2	3	1	3	2	2	1	2	2	1	2	2	2	2	2	1	1	2	3	2	2	2	1	1	2	1
# of Minuses		1	2	0	1	1	0	2	0	1	1	2	1	1	2	1	1	1	1	1	2	2	1	0	1	1	1	2	2	1	2

Figure 12: Pugh chart for John Cocce's 30 concepts.

Concepts Generated by: Jacob Farnham

1. Inverted Clamp

Similar to a 5C collet, the inverted clamp would allow the operator to fix the gland to the face of the tombstone by clamping the inner diameter of the gland using expanding arms.

Evaluation: This is essentially the concept we went with. The collet system is the centerpiece of our device design.

2. "Claws"

Opposite of the Inverted Clamp, "claws" would clamp down on locating features of the gland. By putting the claws in specific locations this would allow the operator to rotate the gland for angled drilling.

Evaluation: This concept is more or less what MAGSEAL currently does. They use clamps and tabs to hold the glands to the machine surface. This essentially would take what they do now and attach it to the machine surface.

3. "Wine Stopper"

Similar to a rubber wine stopper. As a lever is pulled, the rubber end of the cylinder would compress onto the gland and create a seal and hold it onto the fixture.

Evaluation: This concept would not work very well due to the variation of position do to the rubber stopper.

4. Cap

A cylinder with a thread at the end of it. The gland would slide onto the cylinder and a cap would simply be screwed on, fixing the gland to the face of the fixture.

Evaluation: This would work well to secure the gland to the machine surface but the threads would take more time than necessary to remove the gland.

5. Sliding Locking Feature

Clamps sliding in from the sides of the gland would lock onto locating features of the gland allowing the operator to put the gland in the specific locations for drilling the angled holes.

Evaluation: Rather than a fixture device, we ended up using this concept for the locating feature.

6. Two Spring System

Similar to the Sliding Locking Feature, rather than metal clamps, springs would be used to lock onto the gland. A lever motion would activate and deactivate the springs allowing for easy implementation and removal of each gland.

Evaluation: If used on the locating feature the springs would work fairly well. We chose not to implement any springs because of wear and tear and because of the fact that not all springs would be engaged.

7. Quad-Spring System

Similar to previous design, the Quad-Spring System would have four springs locking in on locating features rather than two. Also rather than contacting exterior faces, the four springs would lock into the ears of the gland.

Evaluation: Similar to the previous. Springs would have been excessive.

8. Locking Pins

The gland would slide around a cylinder and locking pins within the tombstone would raise up and contact locating features, within the ears of the gland, to prevent the gland from rotating around its axis.

Evaluation: This concept is one that they currently use but we would apply them to the machine surface.

9. Locking Pins II

Rather than pins rotating into place, a single bar with tabs at either end would raise up in meet those locating faces, similarly to the previous concept.

Evaluation: This would be excessively complicated to properly design and install.

10. Four Sided - 12 Gland Holder (Obsolete)

This represents the tombstone device. Each side would hold 3 glands with the holding mechanisms equidistant from each other. Mechanisms within the tombstone would allow the operator use minimal motions to “lock” and “unlock” glands to the faces of the device.

11. Two Sided (Obsolete)

Similar to the Four Sided device but with only two sides. Each side would hold three glands with the mechanisms equidistant from each other. Internal lever mechanisms would allow the operator to attach and detach glands all at once.

12. Three Sided (Obsolete)

This design is similar to the previous mechanisms, but includes three sides.

13. Revolving Mechanism (Obsolete)

The design was created before Team 30 knew that the mechanism within the CNC machine that MAGSEAL uses can rotate. Initially this idea was to be implemented for the angled holes that need to be drilled. The base would rotate slightly and be locked into place with pins or another locking mechanism.

14. Two Sided Revolving (Obsolete)

This is simply a two faced system integrated with the revolving base mechanism.

15. Three Sided Revolving (Obsolete)

This is simple a three faced system integrated with the revolving base mechanism.

16. Four-Sided Reduced (Obsolete)

This would be very similar to the four sided system but with any excess material removed.

17. Three-Sided Reduced (Obsolete)

This would be very similar to the three sided system but with any excess material removed.

18. Four-Sided Reduced and Revolving (Obsolete)

This is a combination of the previous design concepts including the revolving base as well as the reduced version.

19. Three-Sided Reduced and Revolving (Obsolete)

This is a combination of the previous design concepts including the revolving base as well as the reduced version.

20. Horizontal “Spice Rack” (Obsolete)

This would be a spice rack of sorts for the glands. They would be placed into each cell horizontally sliding around a cylinder. They would rotate around their axis to allow for the angled holes to be drilled.

Evaluation of Concepts 10-20: These concepts involving tombstones and other sorts of multiple sided features are now all obsolete due to the change of our Design Specifications.

21. Twisting Latch

Once the glands are locked into place this twisting latch mechanism would be able to twist 360 degrees at intervals of 5 degrees. This would allow the operator to quickly twist the glands into the next orientation without having to unlock, rotate, then lock again. This would reduce setup time.

Evaluation: This concept would be a good way to 'clock' the glands at specific angles. However it would be hard to implement into the machine surface. One of our goals is for our design to be simple.

22. Internal Rotating Gear System

This would be implemented into a tombstone device. Once the glands are locked into place, to rotate, a knob for each gland on the outside of each face would be turned and the gear system on the inner face of the tombstone would turn each gland on that specific face to the proper orientation.

Evaluation: Similar to the previous evaluation. Any sort of gear system would require lubrication and very precise machining for each gear. Excessive for our project.

23. Internal Rotating Gear System - Single Knob

This would also be implemented into a tombstone device. Once the glands are locked into place, to rotate, a single knob on each face of the tombstone would be turn and the gear system within the tombstone would turn each gland on the specific face to the proper orientation.

Evaluation: Similar to previous evaluation.

24. Internal Belt System

This design is similar to the previous designs. A belt system on the inner face of the tombstone would be wrapped around each locking mechanism. When a knob, or lever, is turned the belts will rotate each gland to the proper orientation.

Evaluation: Any sort of internal system would be difficult to manufacture. This concept was also generated with the idea that a tombstone would be used.

25. Internal Chain System

This design is similar to the previously mentioned concept. A chain system on the inner face of the tombstone would be wrapped around each locking mechanism. When a knob, or lever, is turned the chains will rotate each gland to the proper orientation.

Evaluation: Similar to previous evaluation. A chain system would also require lubrication.

26. "Ferris Wheel"

A much more creative design, the “Ferris Wheel” would have glands tangentially attached on the outer face. When the machining process for one gland is finished, the wheel would rotate to the next one.

Evaluation: This was an overly creative design. It would be very space inefficient and unnecessary.

27. Rotating “Ferris Wheel”

Similar to the previous design concept, the Revolving “Ferris Wheel” would rotate each gland a specific amount as the overall wheel turned. Once the whole wheel completes a single revolution the initial gland will have rotated on its axis to the orientation necessary for the angled holes to be drilled.

Evaluation: Even more ‘ridiculous’ than the previous concept.

28. Four-Sided Auto-Rotate (Obsolete)

Similar to design concept #13, as the base rotates each individual gland would rotate a specific amount as the base rotated. Once the system completes a single revolution the initial gland will have rotated into the orientation necessary for the angled holes to be drilled.

Evaluation: Obsolete.

29. Notched Cap System

The gland is placed onto a cylinder on the face of the device. A cap with pins on the inner diameter slide into notches on the face of the cylinder and a twist lock mechanism holds the gland to the face of the device.

Evaluation: We tried integrating this concept as a quick attach system of the collet to the plate. It proved difficult to machine. The concept was disregarded once our design specifications changed.

30. Insert with C-Clamp

A cylinder with a cap and pin would slide through the gland to the back face of the tombstone device. The pin on the inner face of the insert would be used to locate the necessary angles for the angled drilling. A C-Clamp on the back face of the tombstone device would slide into a notch on the end of the insert and pull it tight against the gland.

Evaluation: This was a top concept for a while before our design specifications changed. Now, nothing can be attached to the back of the plate because the plate is secured to the table top on its back surface.

Below are figures consisting of the concepts generated by Jake Farnham.

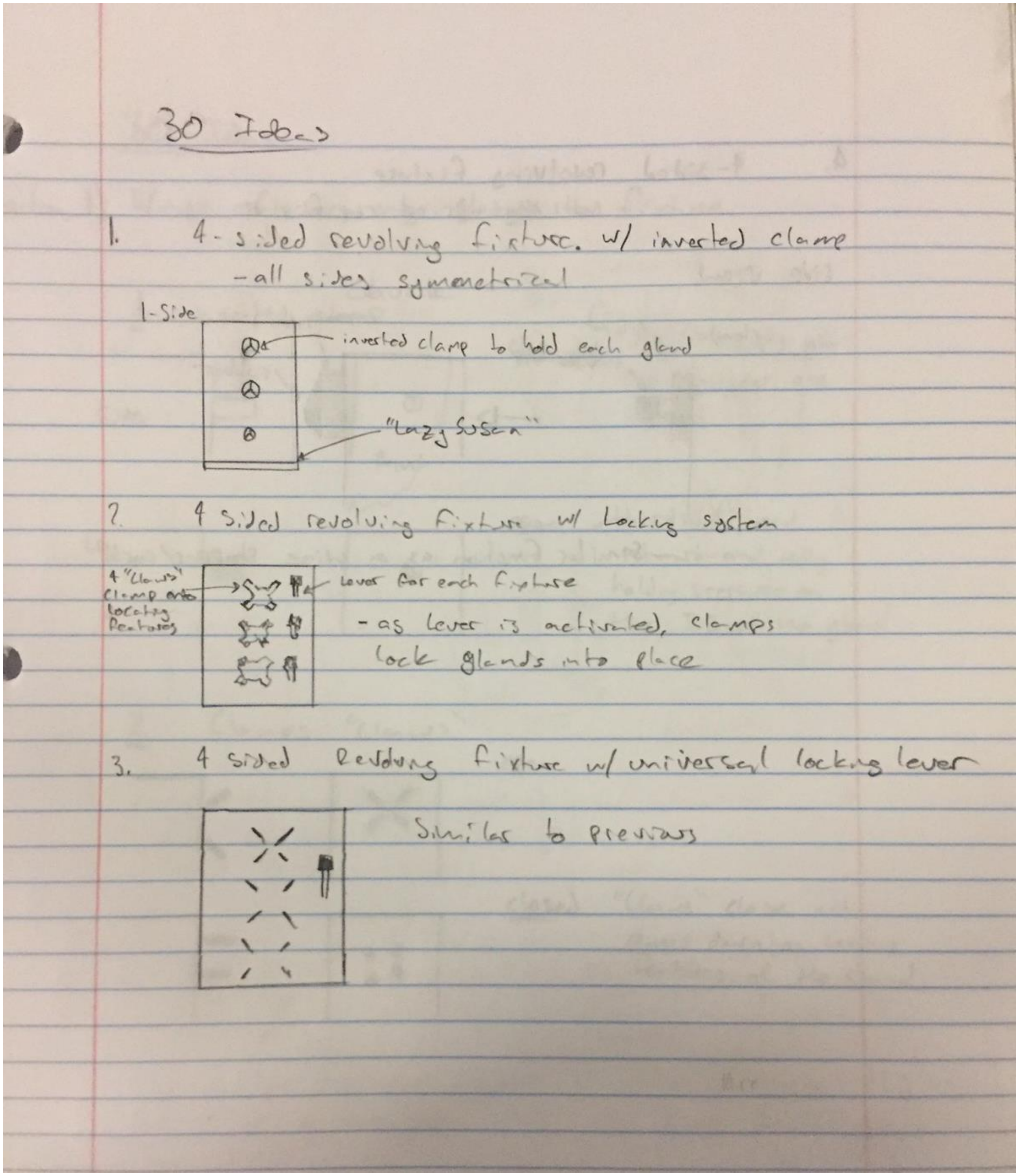


Figure 13: Jake's concepts 1-3.

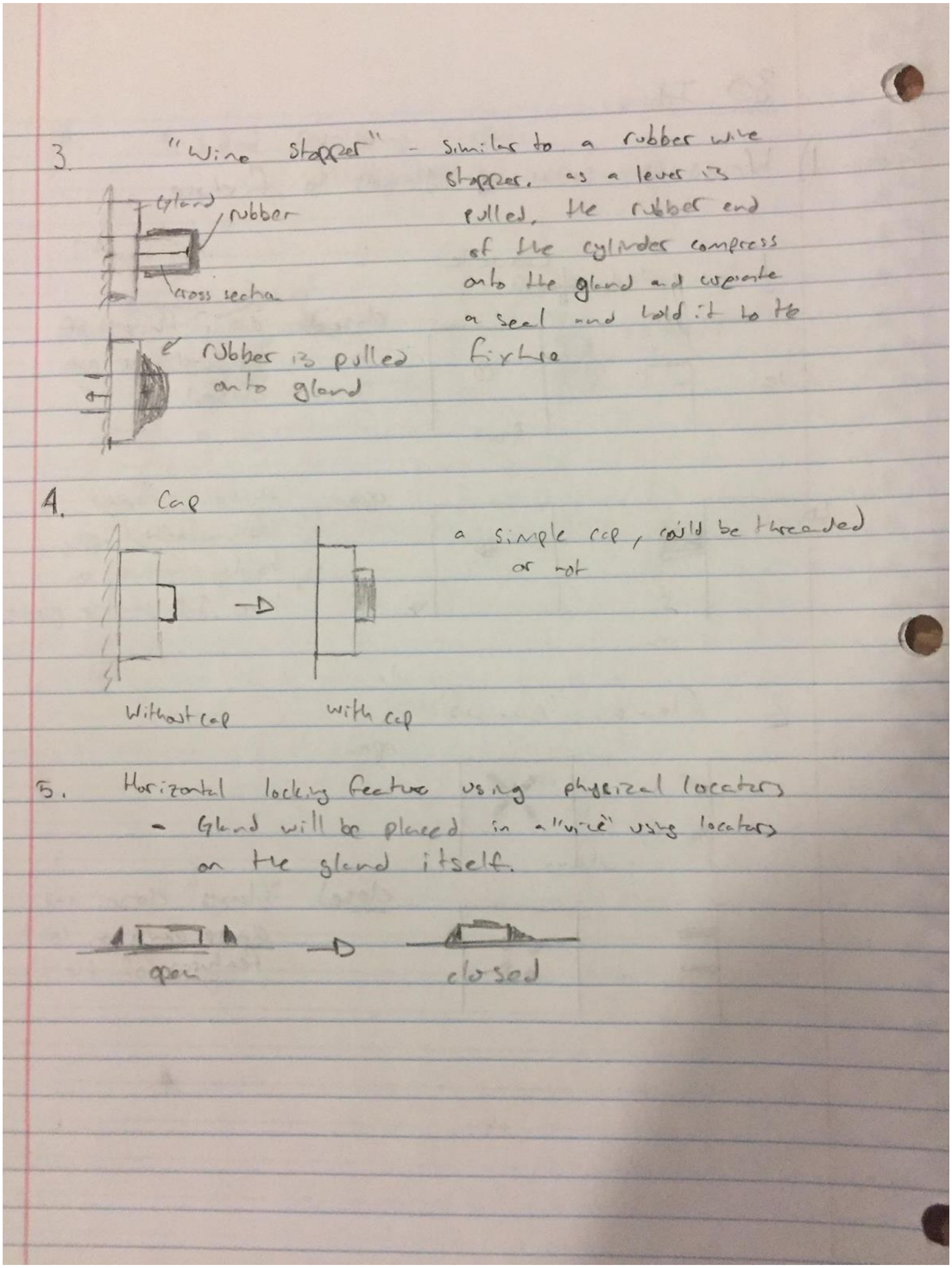


Figure 14: Jake's concepts 3-5.

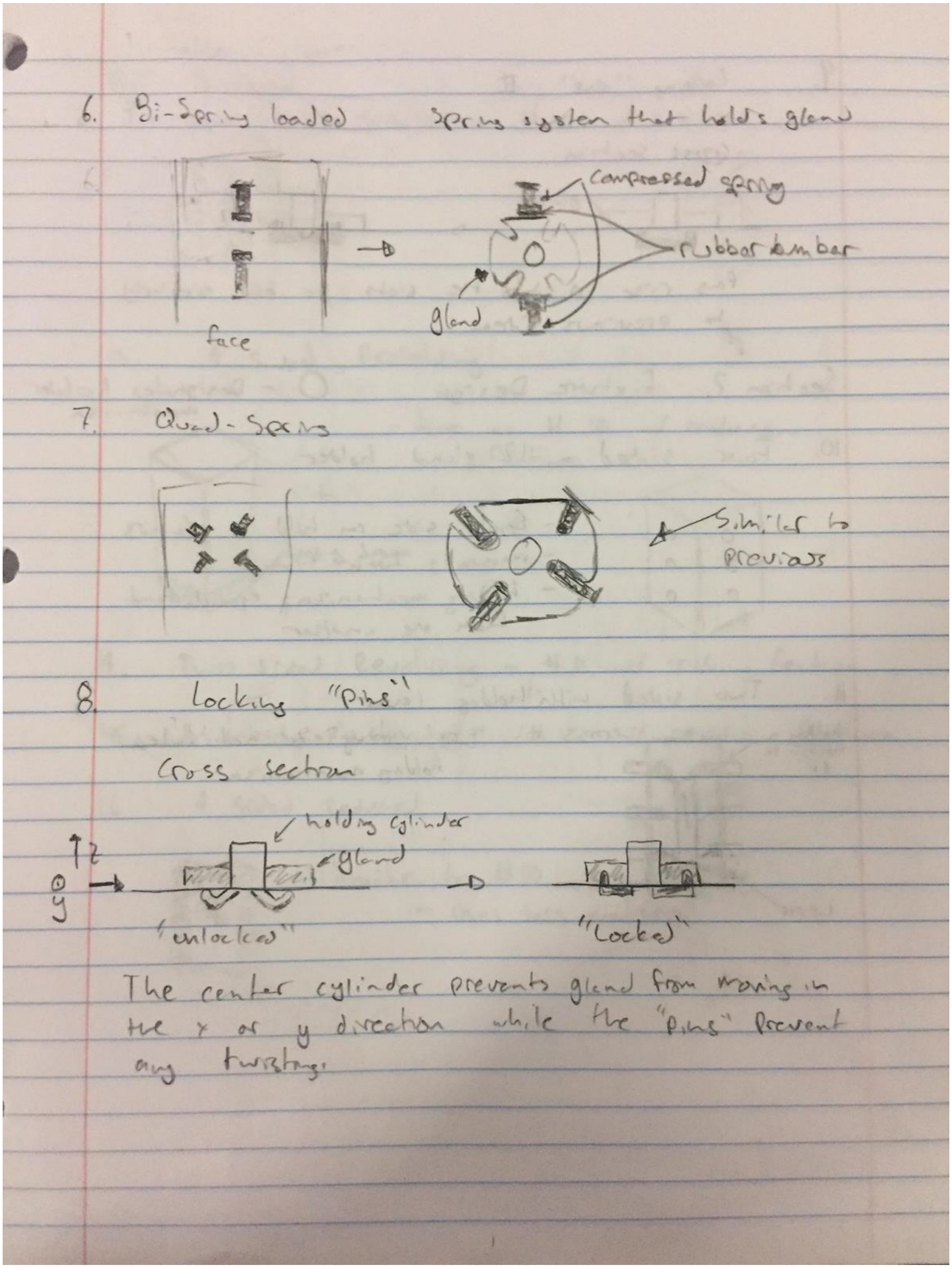


Figure 15: Jake's concepts 6-8.

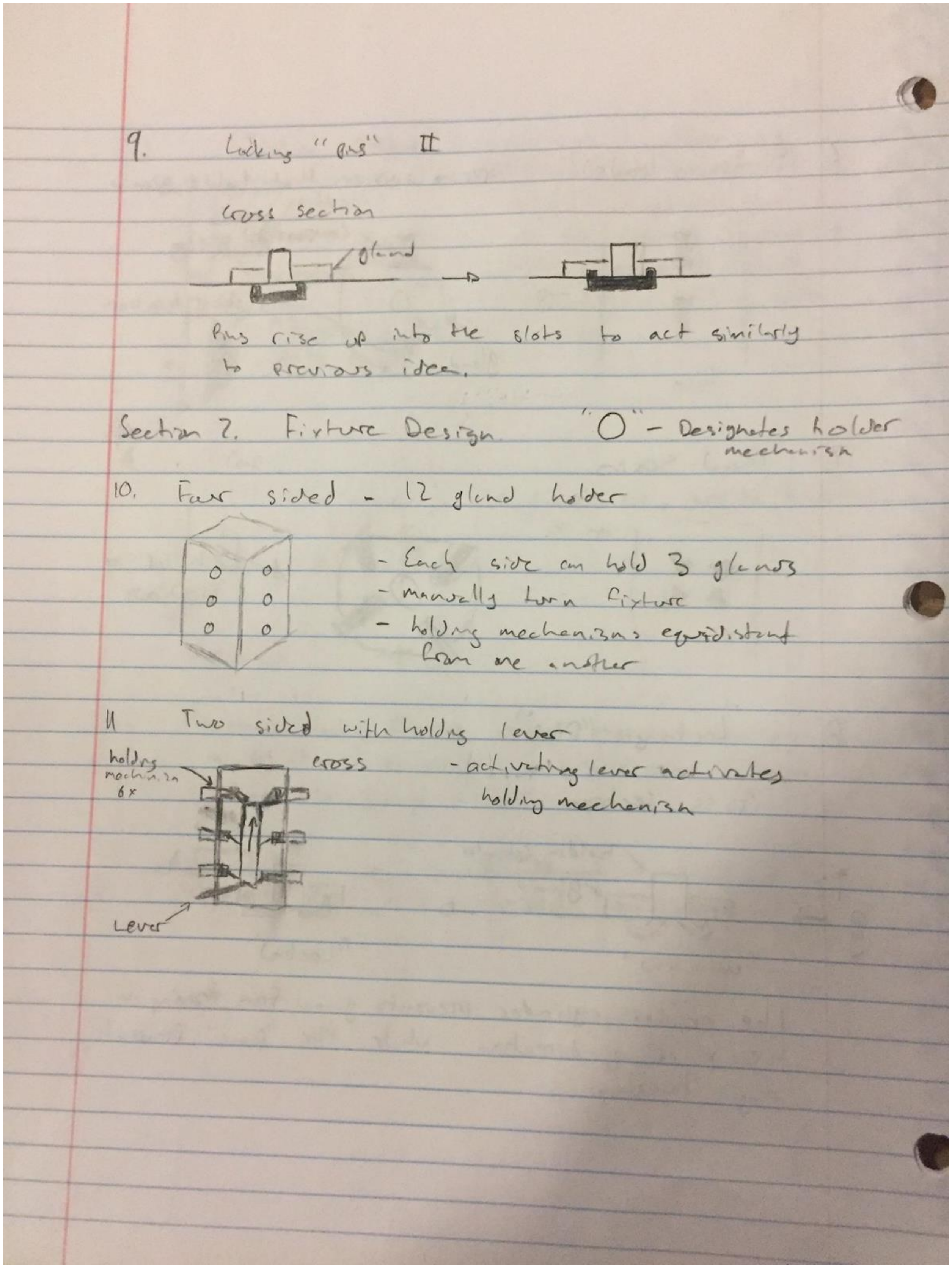


Figure 16: Jake's concepts 9-11.

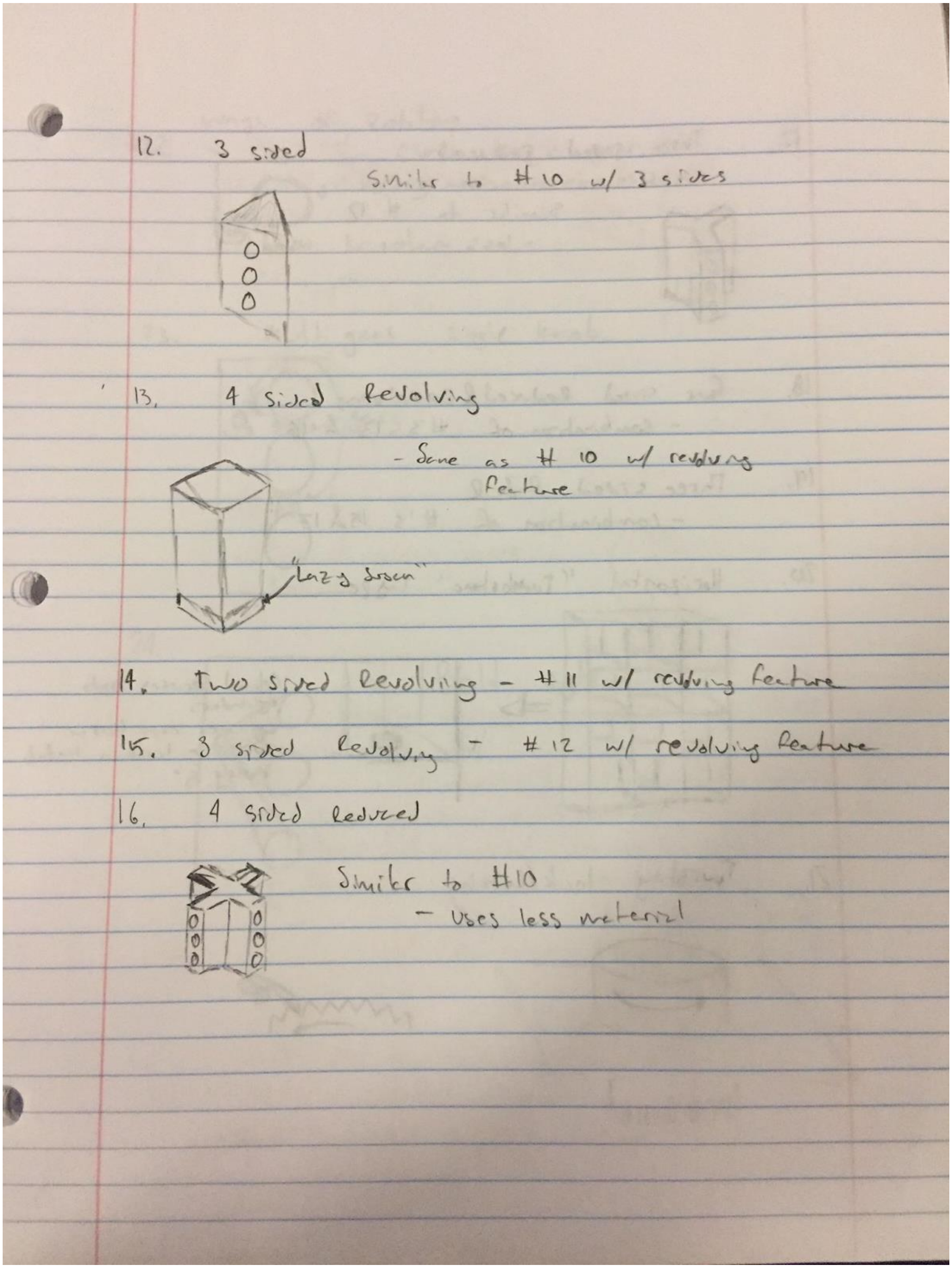


Figure 17: Jake's concepts 12-16.

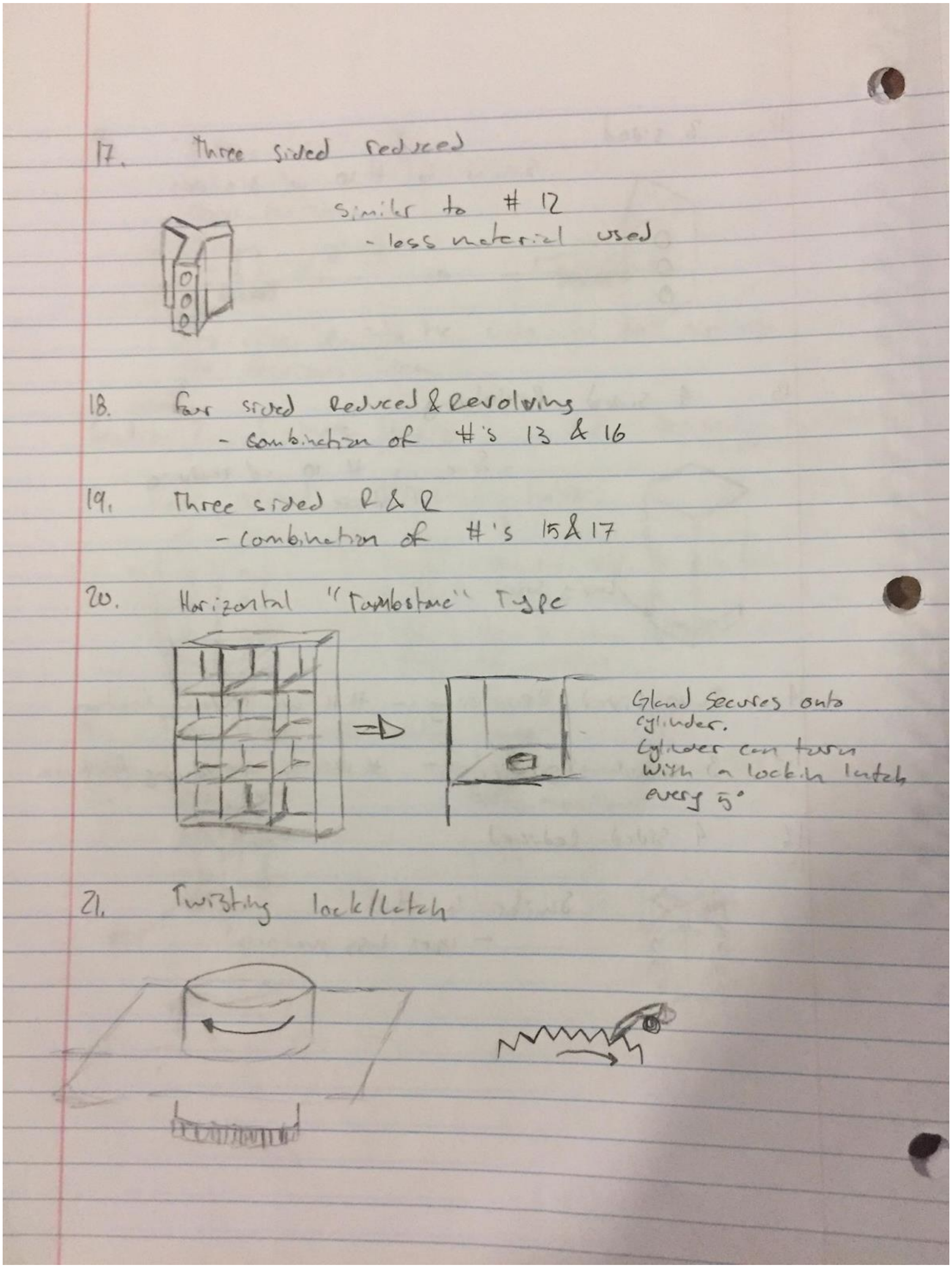


Figure 18: Jake's concepts 17-21.

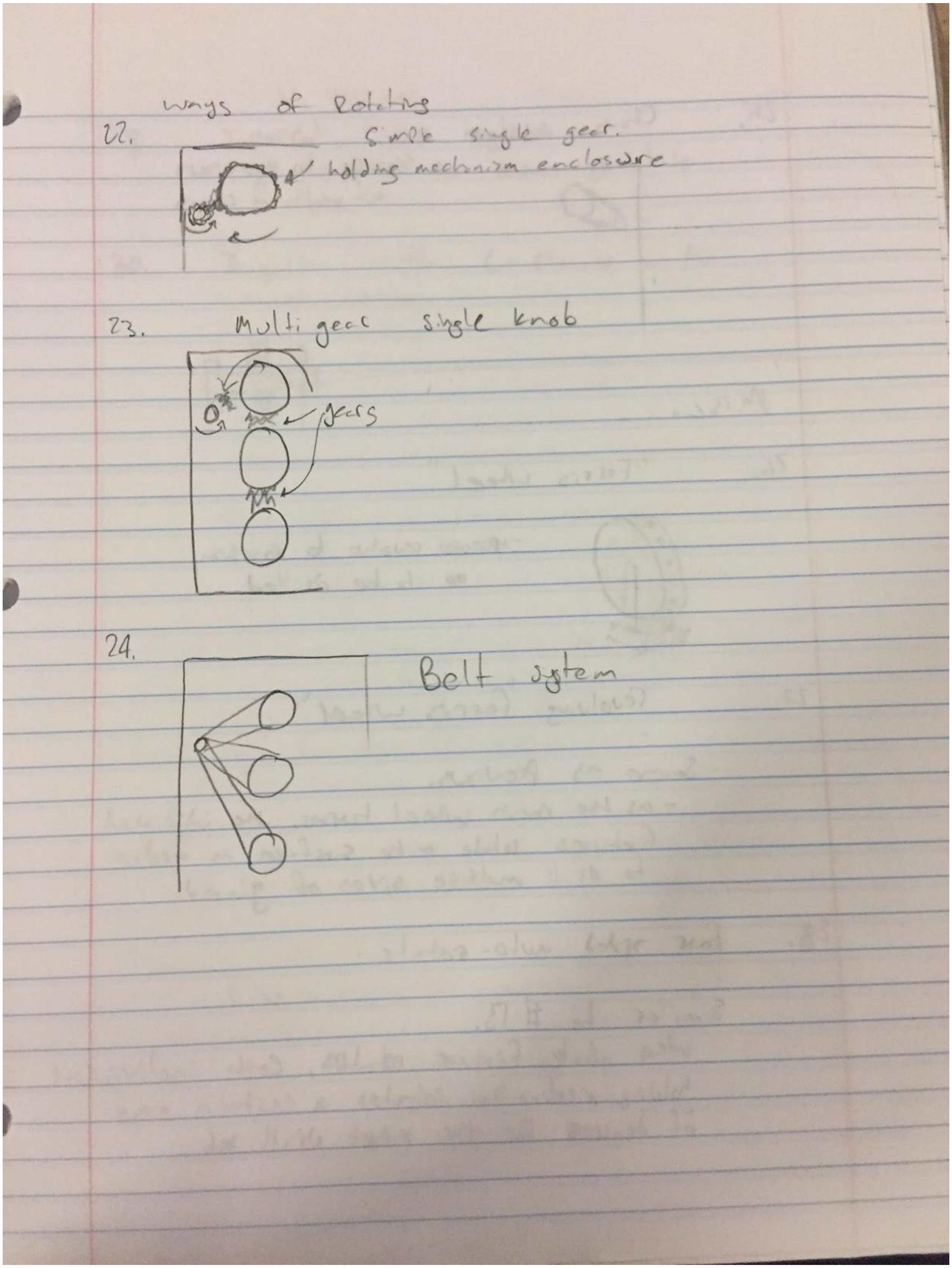


Figure 19: Jake's concepts 22-24.

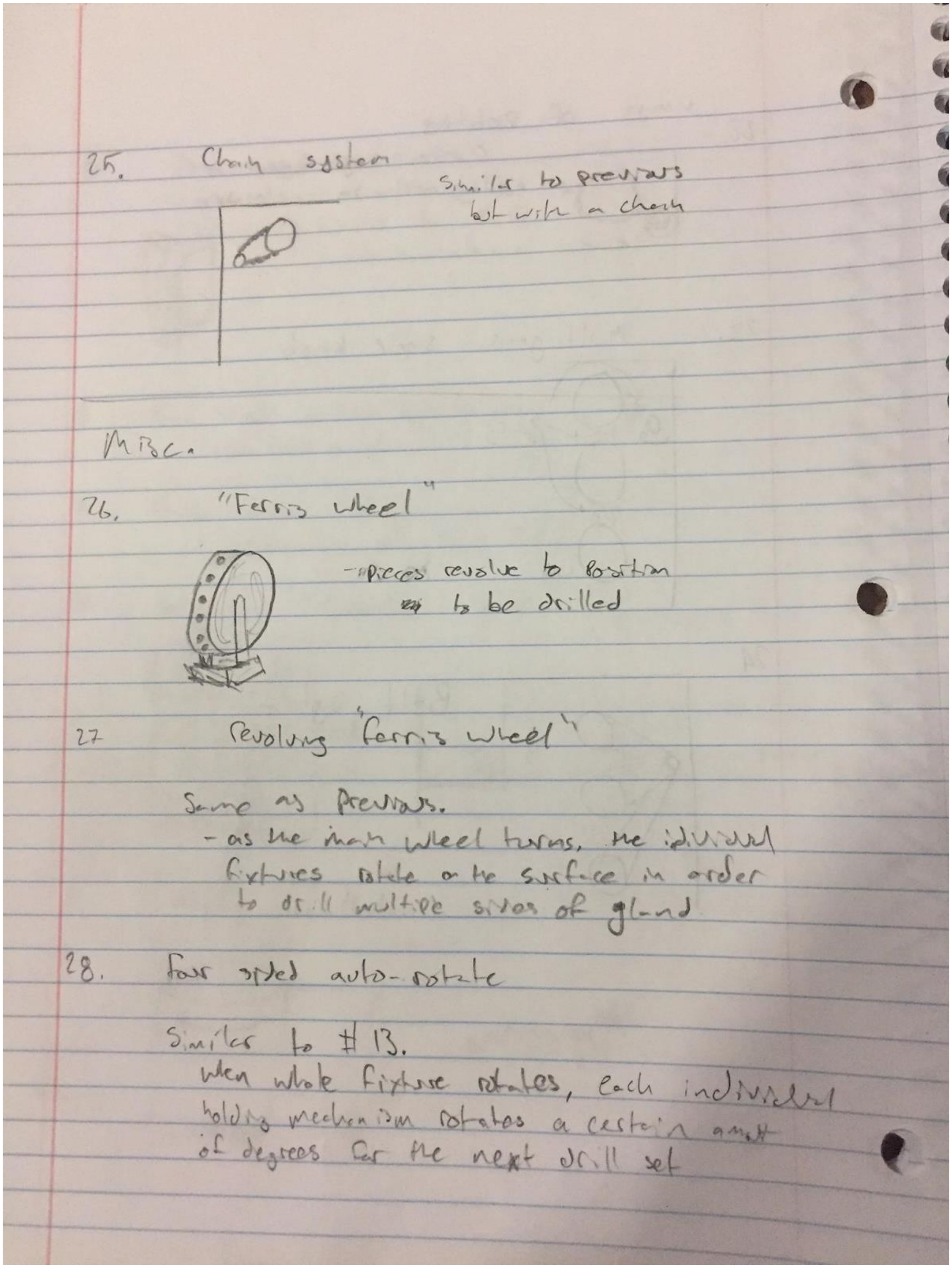


Figure 20: Jake's concepts 25-28.

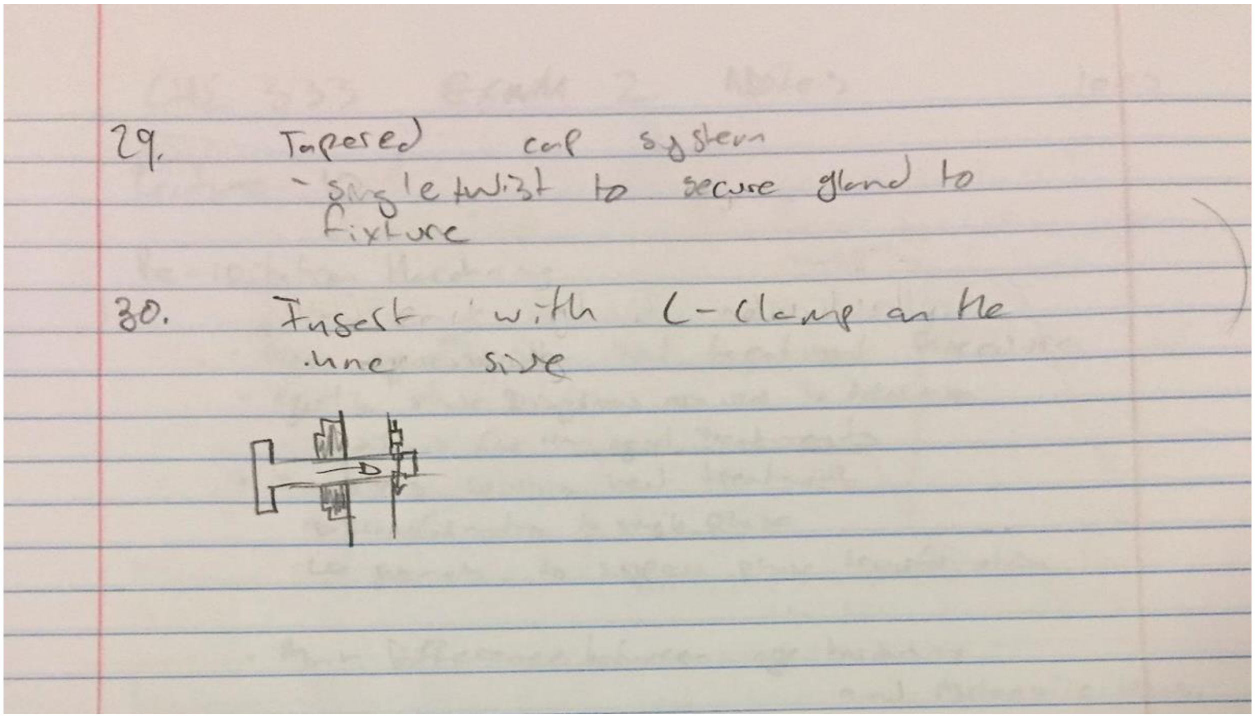


Figure 21: Jake’s concepts 29-30.

		Concepts																													
Engineering Criteria	Reference Concept	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ease of use	28										-	-	-	-	-	-	-	-	-	-	-						+	+			
Longevity	28											-						-	-	-							-	-			
Number of Glands	28											-	-		-	-		-		-											
Size	28											+	+		+	+	+	+	+	+	-						-	-			
Complexity	28										+	+	+	+	+	+	-	-	-	-	-						-	-			
Number of Parts	4	-	-	-		-	-	-	-	-																					+
Ease of use	4	+	+	+		+	-	-	+	+																				+	-
Longevity	4	-	-	-		-	-	-																						+	-
Number of Parts	21																						+			-					
Complexity	21																						+		-	-					
Ease of use	21																							+							
# of Plusses		1	1	1		1	0	0	1	1	1	2	2	1	2	2	1	1	1	1	0		2	1	0	0	1	1		2	1
# of Minuses		2	2	2		2	3	4	1	1	1	3	2	1	2	2	2	4	3	4	3		0	0	1	2	3	3		0	2

Figure 22: Pugh chart for Jake Farnham’s 30 concepts.

6. QFD

At the time our top designs were based on the number of sides of the base device. We concluded that the four-sided fixture would be the best overall. The next best would have been the single plate.

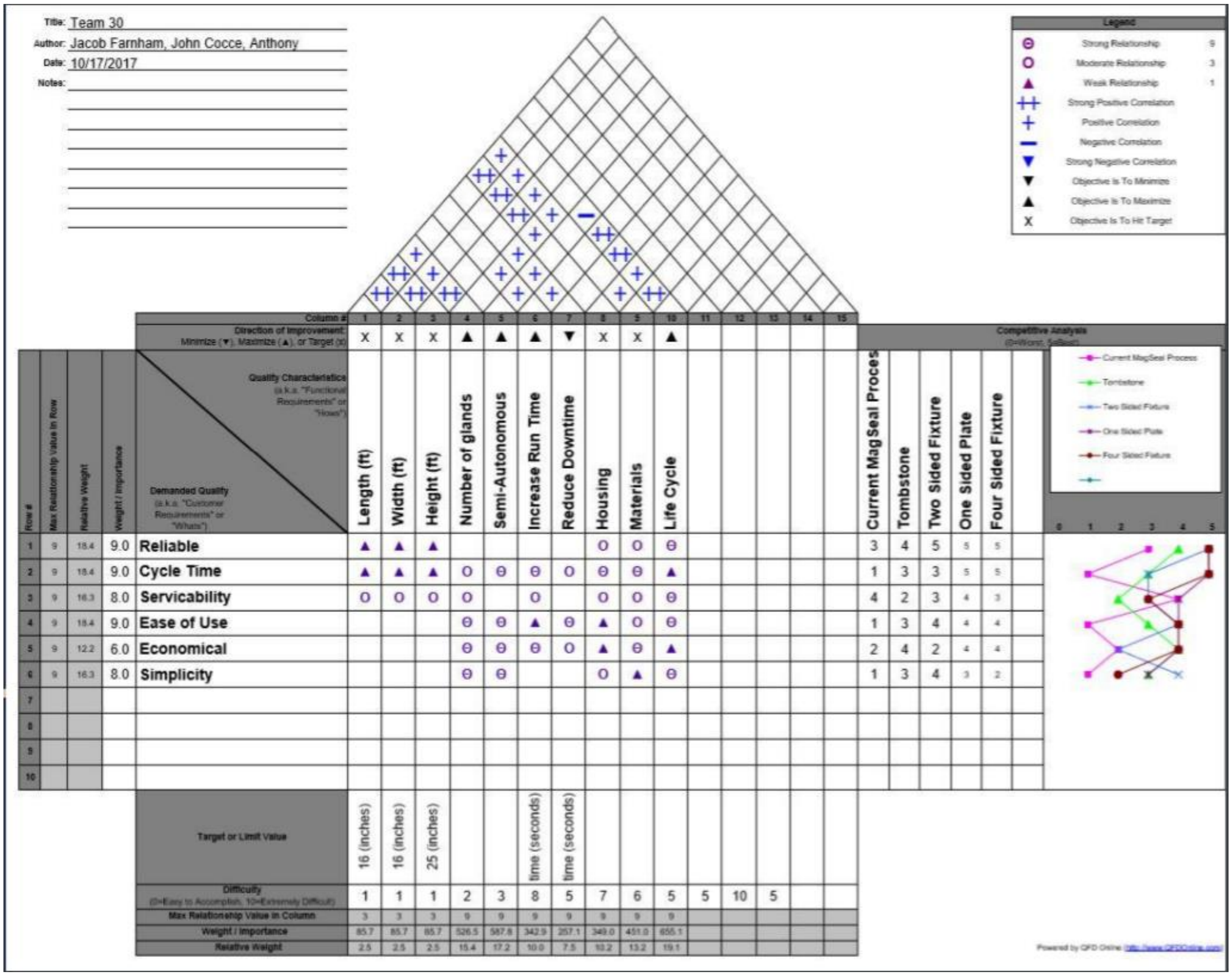


Figure 23: QFD chart of various concepts.

Team 30 decided on six specifications to rate design concepts:

1) Reliability:
    a) Operator's ability to put the glands in the machine and "forget" about it until the glands need to be changed.
2) Cycle Time:
    a) How long the machining process takes from start to finish, including setup time.
3) Serviceability:
    a) How difficult the design concept would be to repair any technical difficulties that would arise.
4) Ease of Use:
    a) Similar to reliability; how easy it would be for the operator to use.
5) Economical
    a) How much more efficient the concept is compared to the current process.
6) Simplicity
    a) How mechanically simple the design concept is, i.e. number of moving parts, etc.

Each design has its pros and cons:

The four sided "tombstone" device would be able to hold roughly twelve glands. This would allow the operator to create more glands in less or the same amount of time as the current process. Considering setup time would remain the same for a single gland at a time versus 10-14 glands a time, the overall efficiency would increase. On each face of this device, the glands would be able to rotate around their axes to the specific orientations for the angled drilling.

The single plate idea would be able to hold three to four glands on a single face. Having a single plate being able to attach onto an existing tombstone within the machine would allow the operator to prepare the next plate or plates while the glands in the CNC machine are being drilled. This would be less expensive than purchasing and modifying a tombstone to the specific needs. The plate is easily implemented, cheaper, and different plates can cater to the different geometries of different sized glands.

The main concept design by Team 30 has changed since then. A four sided tombstone with a rubber seal stopper is the top design. The design specifications will be explained in the Proof of Concept section.

Because this product is not intended to be sold commercially no market analysis needs to be performed. MAGSEAL would like this product for their own personal use with no intentions of selling the design at this point in time.

7. Design for X

Safety

It is the goal of any project of the production of a device to make sure it can be operated safely. One issue that occurs in machining processes is if something is not properly secured the amount of force by the machine can cause the workpiece to be launched at high speeds. Most machines have safeguards in the form of shields to protect the operators, and others in vicinity, from being hit by potential projectiles. We made sure that all the pieces used in this device are properly secured by using durable metals and large clamping forces.

Another safety concern is any time an operator is using a machine there are imposed risks: chips can fly off in any direction or drill bits can break. These risks happen at random, in most cases, and the best way we could cut down the risks is by reducing the amount of time the operator needs to be around the CNC machine. Similarly, the different cutting oils, coolants, and chemicals pose health risks and by reducing the amount of time the operator is around the running CNC machine it also reduces the amount of time the operators is around hazardous chemicals.

Manufacturability

Since our project goal is to expedite a machining process we have to design our device to increase the manufacturability of the glands. We did that by using as many universal parts as possible. This means that one part, or set of parts, can be used for any gland. This cuts down on the time needed to switch set parts or set up time which allows the operator to produce more glands. The only parts that would potentially need to be switched are the collets themselves. All the collets used are the same part. This means that the only difference between collets is the amount of material that was taken off to account for the different sized glands. Since all collets are the same part, this means that interchanging the different sized collets is much quicker. If different collets entirely were used then multiple aluminum base plates would need to be used. These plates are very large and heavy. Interchanging aluminum base plates all together would be a whole process in itself. Since we kept each part of this device as universal as possible we have cut down on any potential time needed to switch parts or change processes.

We also had to design our device in a way that would be easy to manufacture in-house. Each part is machined out of stock which is easily obtainable. Each part was designed with the machining process in mind. For example, fillets were added in sharp corners of the aluminum plate because sharp corners are near impossible to CNC. Any thread we used, that was not part of a specific function, we set to be a common thread type of 10-32. This only requires a single tap for most of all the screw holes. As stated in the previous paragraph, we kept as many parts and functions of this device as universal as possible.

Reliability

Any device is unable to work if it cannot reliably perform its function. In our case we had to design our device with durable metals. All parts, other than the aluminum baseplate, were made of steel; the slider mechanism was made of entirely A2 Tool steel. It yields a high amount of surface finish and it is a very hard metal. This adds a high amount of reliability and longevity to the device. The clamping force of the collet is rated up to 10,000 pounds. This is plenty of for to keep the gland secure and prevents it from moving during the machining process.

Ease of Use and Repeatability

We designed this device with the operator in mind. We wanted this device to be intuitive and easy to use. By looking at the device the operator can understand what is going on and what each part is for. The current process has many pins and clamps involved with a single gland; our design only has four moving parts but only two are engaged at a single time. As previously stated, we tried to keep everything as universal as possible. This reduced the amount of parts needed. Fewer parts means a simpler product. These factors contribute to high repeatability and ease of use.

8. Project Specific Details & Analysis

The main reason for the development of the Delta Seal gland fixturing device is to speed up the time of production. Production needs to speed up in order to increase the number of units that are produced per day at MAGSEAL.

The current process to prepare the gland seals for machining is time consuming and arduous. One gland seal can be machined at a time and the loading process requires a series of various diameter dowel pins and between two to four rubber stops. An image of the rubber stops can be seen in Figure 24. This image features the rubber stops before they have been mounted to the aluminum plate with the dowel pin holes. The reason for having the different sized dowel pins is so that both the smaller and larger sized gland seals can be machined. First, these pins are dropped into an aluminum plate, and then the gland seal is secured into place with the dowel pins positioned between the ears of the gland seal. The machinist must remove these pins every time a different sized gland seal needs to be machined. Also, the machinist must remember which holes the dowel pins must go into depending on the angle of orientation of the ports that must be tapped into the seal. The machinists also have to walk back and forth between two work benches featuring different dowel pins, wrenches, Allen keys, etc. that are necessary for swapping the mounting equipment for the smaller and larger sized gland seals. The load time of this process will run an experienced machinist such as Kevin, a Delta Seal machinist at MAGSEAL took 47 seconds to load in a seal and lock it down. It then took him 2 minutes and 4 seconds to interchange between a larger and smaller sized seal that was to be clocked at a different orientation. The portion of the shop layout that the team is concerned with is illustrated in Figure 25.

Figure 24: Machinist Denis of MAGSEAL illustrates the current clamp mechanism with a series of rubber stops, which is an arduous process to set up.

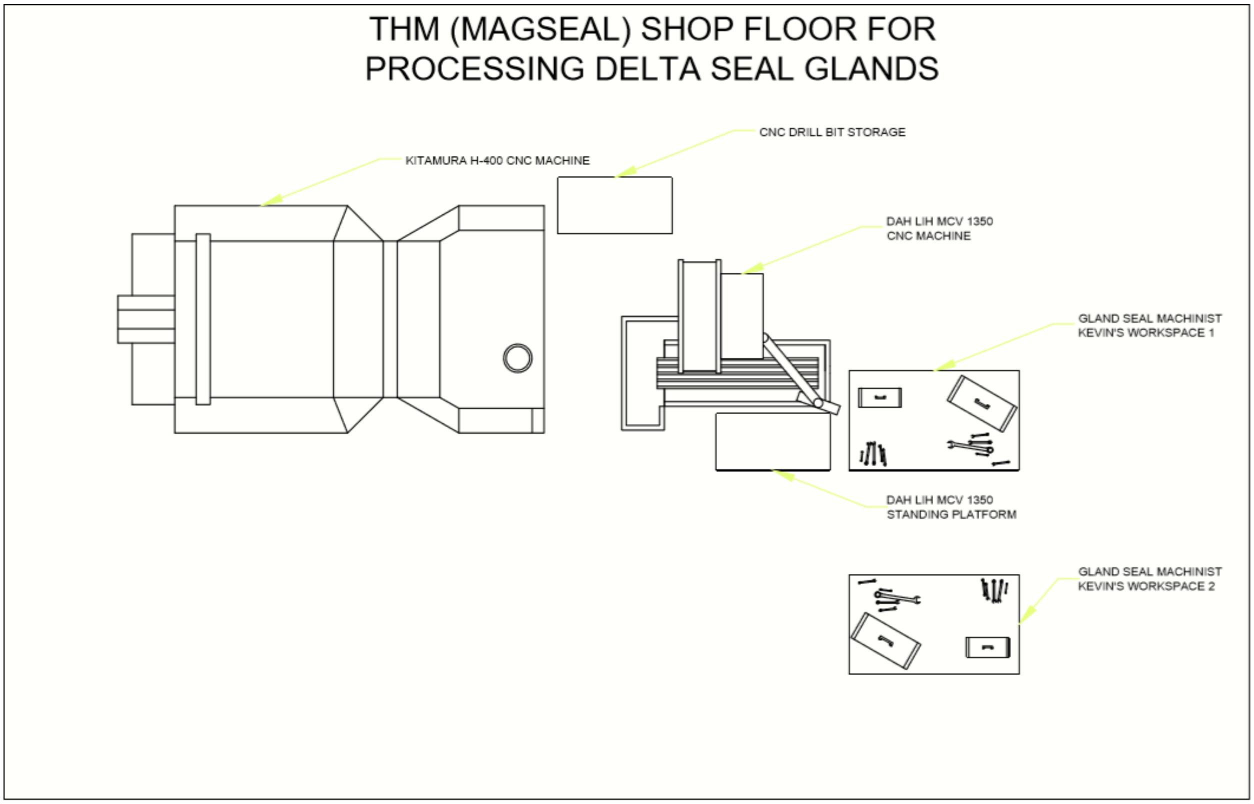


Figure 25: Above is a layout of the equipment that Capstone Team 30 is tasked with working around. With the creation of the Delta Seal gland fixturing device, Kevin will no longer need to go back and forth between both of his work benches or use a multitude of tools to set up the fixturing device.

The Delta Seal gland fixturing device that Capstone Team 30 developed allows the modified Mitee Bite ID XPansion collet and the slide-lock mechanism to be in one entire unit. The only piece that must be removed on this device is the modified collet, depending on the size of the gland seal that is to be machined. Unlike the previous dowel pin design, the slide-lock mechanism is universal and can slide on a track and set with a thumb screw for both the smaller and larger sized gland seals. The outer flange of the modified collet is 2.972”, and since the original off-the-shelf collet can be modified to accept both small and large sized gland seals, the counterbore in the aluminum base plate can remain the same size regardless of what size gland seal is loaded in. An example of both collets turned down for their respective seal sizes can be seen in Figure 26. The universal counterbore in the aluminum plate and the rectangular extrusions for the slide-lock mechanism can be seen in Figure 27.

Figure 26: The modified Mitee Bite ID Expansion collets turned down to for the larger sized gland seal (left) and the smaller sized gland seal (right). The flange diameter for both pieces is the same and allows for quick changeability and less custom parts.

Figure 27: The aluminum base plate has a counterbore for the collets to be easily interchanged. It also has rectangular extrusions for the slide-lock mechanisms depending on the angle needed for drilling. Unlike the previous design, both the clamping and orienting features are all comprised in one unit.

Capstone Team 30 conducted a test to demonstrate exactly how much faster the new Delta Seal gland fixturing device really was. The only shortcoming to the testing conducted was that the slide-lock mechanism had not been completed, and therefore could not be set into the aluminum base plate. It is important to note that the team members conducted this test, so a machinist by trade such as Kevin at MAGSEAL would most likely be a bit faster. An overview of the test results obtained can be found in Table 2.

Table 2: The table below features one loading and two unloading tests conducted by the members of Capstone Team 30.

Load Test No. 1	
MCE 402 Team #30	Record of Individual Test
Name of Tester	Jacob Farnham, John Cocce
Date of Test	05/01/2019
Time of Test	4:20 PM
Description of Test	Load Time
Test Parameters	Timed the process of loading the collet onto the aluminum plate an secured a gland seal to the collet.
Results of Test	14.75 seconds
Resolution if Needed	None
Unload Test No. 1	
MCE 402 Team #30	Record of Individual Test
Name of Tester	Jacob Farnham, John Cocce
Date of Test	05/01/2019
Time of Test	4:55 PM
Description of Test	Unload Time
Test Parameters	Time the unload time from collet off the plate.
Results of Test	18.06 seconds
Resolution if Needed	Have a proper Allen Key socket

Unload Test No. 2	
MCE 402 Team #30	Record of Individual Test
Name of Tester	Jacob Farnham, John Cocce
Date of Test	05/01/2019
Time of Test	5:10 PM
Description of Test	Unload Time
Test Parameters	Time taken to change the orientation of the gland seal from one slider to another
Results of Test	40.14 seconds
Resolution if Needed	Theoretical tests; sliders not fully machined.

The results of the first test found in Table 2 where the team members loaded a Delta Seal gland into the collet and tightened it down. The aluminum base plate began with no devices attached to it, and the team used a stopwatch to measure the time it took to load the collet on and secure it into position as well as tightening the collet to expand and secure the gland seal. The total time measured was 14.75 seconds to complete this process.

The second test conducted in Table 2 was the loosening of the collet, followed by the unloading of the gland seal and the collet from the aluminum plate. The process took a total of 18.06 seconds.

The final test results found in Table 2 are the loosening of the collet, rotation of the gland seal, and then the retightening of the collet. This test is a rough estimate because the machining of the slide-lock mechanism had not yet been completed. So 15 seconds were added to this test in order to mimic about how long it would theoretically take to loosen and tighten the different thumb screws found within the individual sliders.

9. Detailed Product Design

At the end of the fall semester Team 30 had designed their product to work with a large tombstone device. As we continued to design what is now our final product, we had more space to work with. The difficult part is having enough space to orient the sliders correctly around the center collet. The important angles to keep in mind are the angles of the flush and drain ports as well as the ports on the top and, potentially, bottom, of the glands. We measured these angles to be 10 degrees above the horizontal axis on either side of the gland. This meant that the slider mechanisms, on the tombstone, could be oriented using the full 360 degrees around the center collet. Specifically, 10 degrees counter clockwise, 135 degrees counterclockwise, and 100 degrees clockwise all from the positive x-axis from the center of the collet. When the problem definition changed to use the aluminum plate instead of the tombstone, the design had to be adjust from 360 degrees to only 180. Since our slider mechanisms took up 2”x1.75” on the plate, adjusting the ‘clocking’ or the specific angle the sliders need to be at to properly locate the glands, became another challenge. The amount of space that could be used was cut in half. However, the proper angles are still possible at -45 degrees, 10 degrees, and 55 degrees; all measured from the negative y-axis.

The dimensions of the aluminum plate are 24” by 12” by 2”. The center of the collets are located 3.75” above the center horizontal of the plate. The far left collet is 8.75” to the left of the center of the aluminum plate, the middle collet is centered right on the y-axis of the center of the plate, the right collet is centered 8.75” to the right of the center y-axis. The cut-outs for the slider mechanisms are at the angles of -45 degrees, 10 degrees, and 55 degrees; all measured from the negative y-axis. The cutouts are 2”x1.75” with fillets with a radius of 0.13 inches at each corner, tangent with the theoretical intersection with the vertical and horizontal edges.

The cutout for each collet is a diameter of 2.975 inches. All collet cutouts are centered at the points specified above. A hole is drilled and tapped at the center of each collet cutout at 1.25” from the surface of the aluminum plate. These holes are drilled with a 21/32 sized drill. A tap is used to accommodate for a 5/8-11 helicoil insert. The helicoil is inserted to accommodate for the bolt of the collet. This helicoil is installed to counter any wear and tear from continually inserting the bolt; if the helicoil gets damaged a new insert can be easily installed. The machined section on the right of the plate is mirrored on the center and the right of the plate.

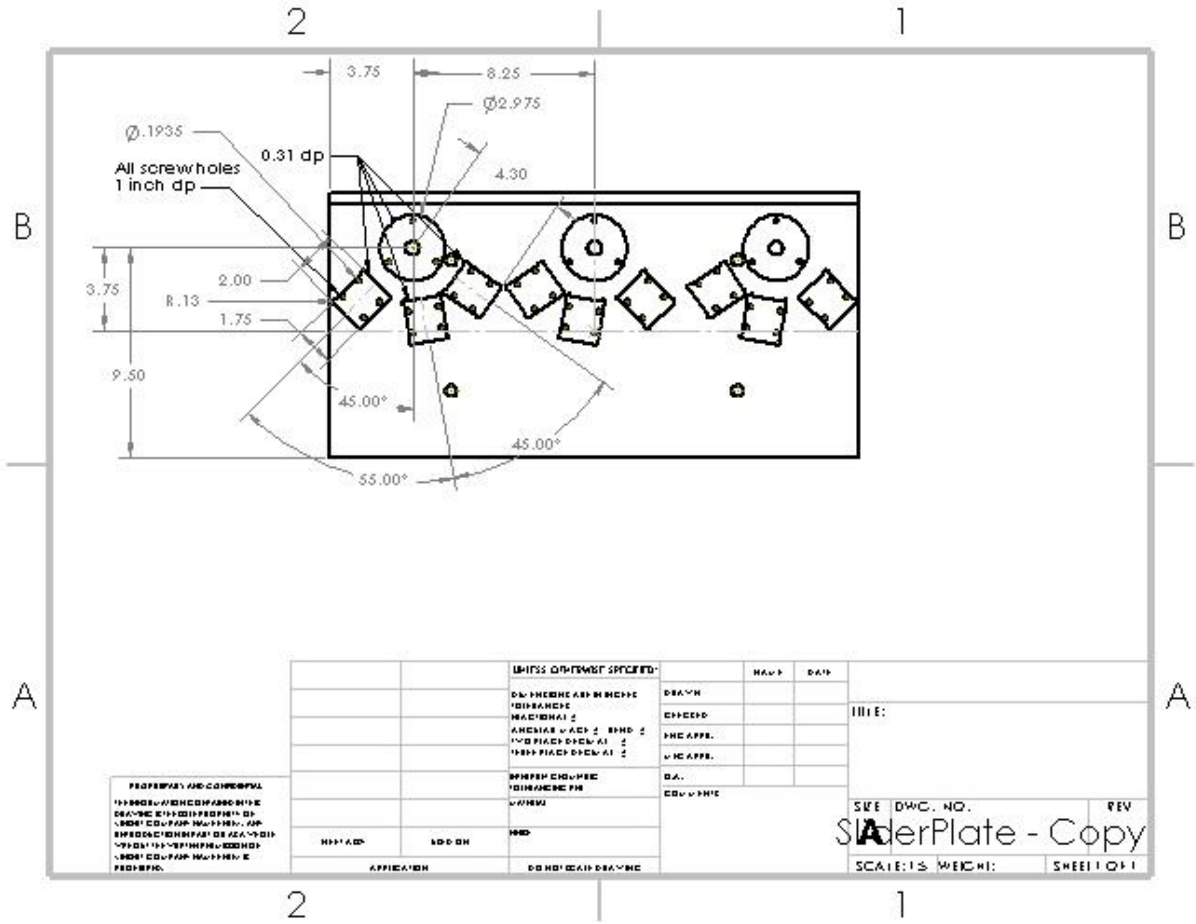


Figure 28: Drawing of the Aluminum Base Plate.

The slider mechanism consists of three separate parts, not including the screws. The slider base, the slider plates or tabs, and the slider itself. Per slider base cutout, two holes per side are centered 0.2” from either vertical edge and 0.5” from the horizontal edges. These holes are tapped with a 10-32 thread. The entire aluminum plate is machined in a CNC machine at the MAGSEAL THM workshop.

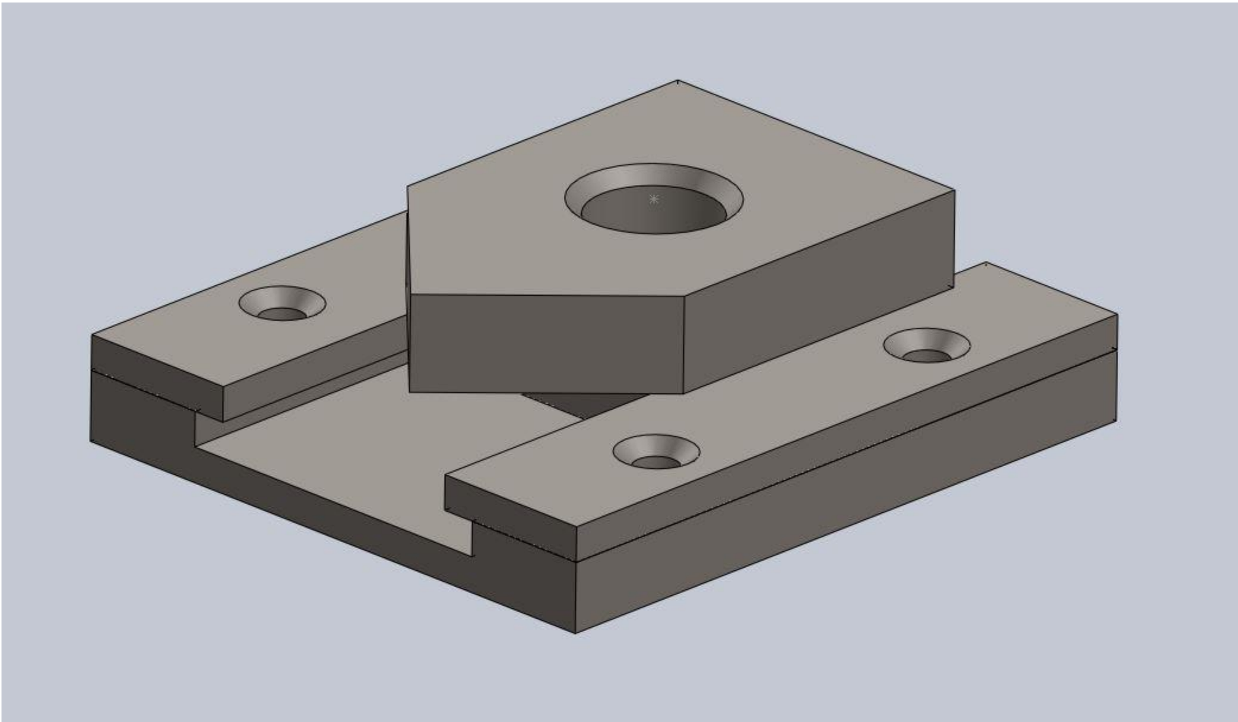


Figure 29: 3-D rendering of the slide-lock mechanism.

The slider base is a 2” by 1.75” by 0.2” piece of A2 Tool Steel. There is a channel with a depth of 0.1” cut out in the center of the base with a width of 1”. These pieces are designed to act as a sliding base for the slider. If the slider had been design to interact with the surface of the aluminum plate then the aluminum plate would see much more wear and tear. This means that if it had been designed that way that once the “slider base” sections of the aluminum plate become unusable due to the sliding, then the whole plate becomes useless. Since these bases are designed to be consumable, that means that once these pieces see enough wear and tear to become unusable then a new piece can be machined and the aluminum plate remains unscathed. To attach the slider base to the aluminum plate four holes per base are tapped. Per slider base, two holes per side are centered 0.2” from either vertical edge and 0.5” from the horizontal edges. These holes are size #4, or a diameter of 0.209 inches. These holes are not tapped. These pieces are manufactured with A2 Tool steel using a Bridgeport machine.

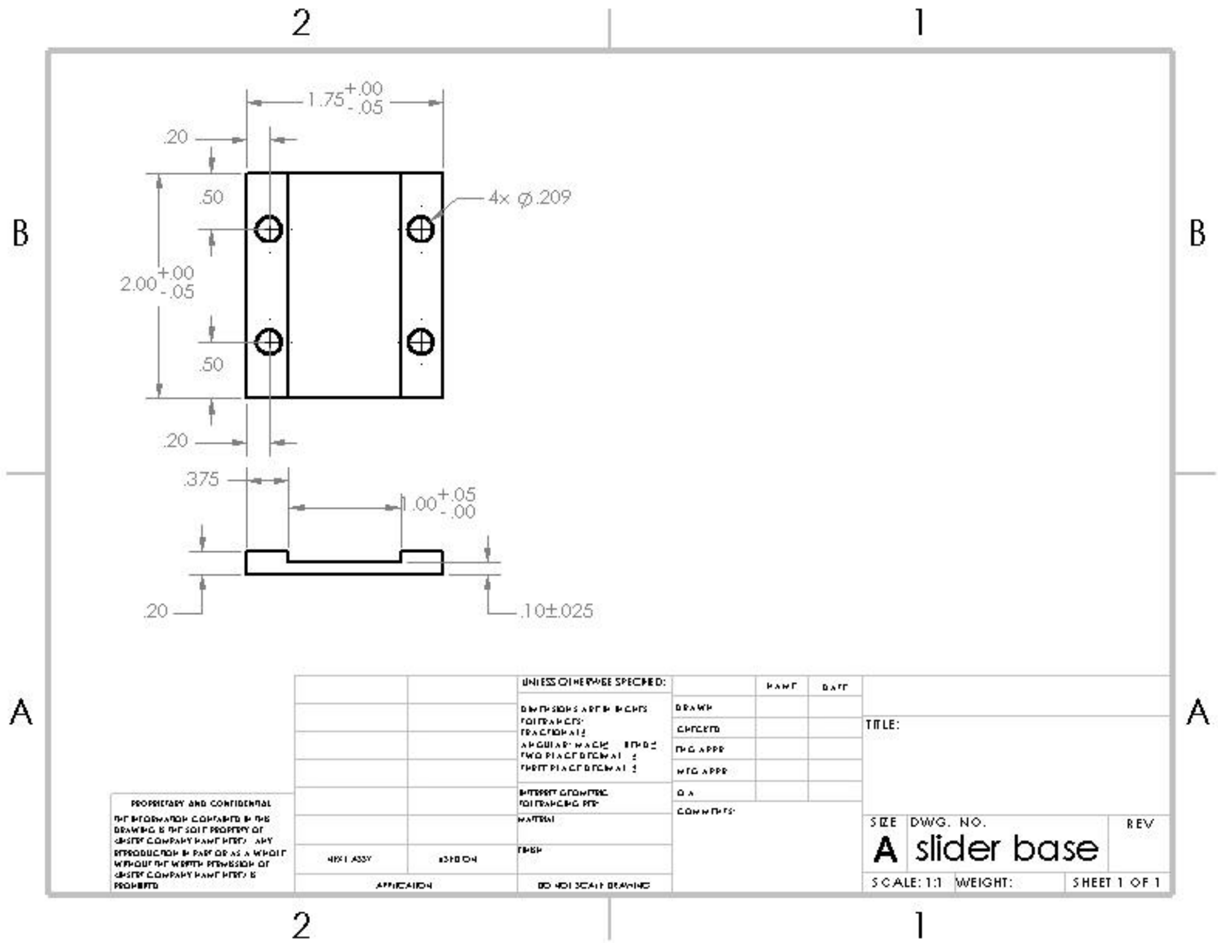


Figure 30: Shop drawing of the slide-lock base.

The slider plates, or tabs, are also manufactured using A2 Tool steel. These pieces' overall dimensions are 2"x 0.475" x 0.1" with holes drilled in the same locations as those above. These holes are also untapped. The purpose of these tabs is to prevent the slider from disengaging with the rest of the mechanism. These tabs hold the slider onto the base.

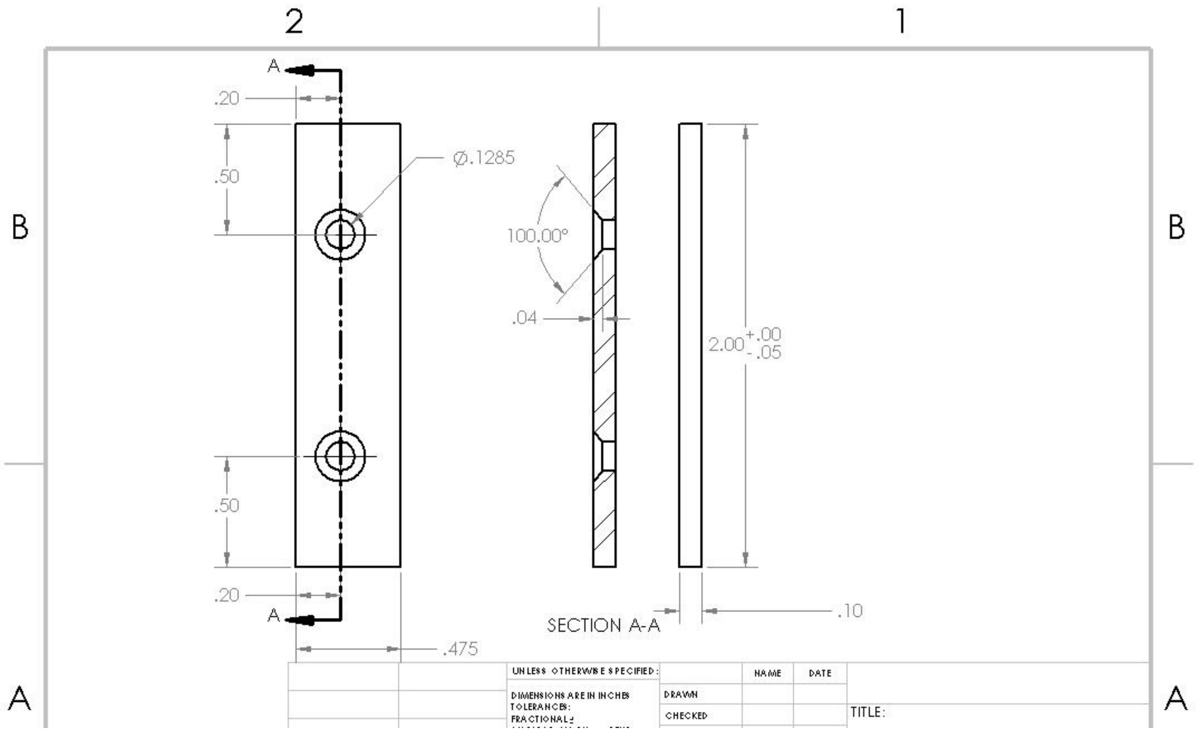


Figure 31: Drawing of slide-lock channel retainer.

The slider is also made with A2 tool steel. The overall dimensions of the slider, viewing from the top plane, are 1" x 1.5" x 0.5". One inch from the back of the slider, on either side, there is a 45 degree cut that forms a point on the center axis of the slider, forming a ninety degree corner. A hole will be tapped and centered on the vertical centerline 0.6" from the back of the slider. This is tapped with a 10-32 thread to accommodate the thumb screws. The edge of this thread has a chamfer of 0.4"x 45 degrees. Viewing from the front plane, two notches are cut out on either side of the slider. The top of each notch is 0.225" from the bottom of the slider and the bottom of the notch is 0.1" measured from the same datum. Each notch is cut 0.125" into either side of the slider. These notches form the channels for the slider tabs. Looking at the right plane, there is a cut out 0.925" from the back of the slider. This cut out is 0.225" from the bottom of the slider. Both of these dimensions have a tolerance of plus 0.05" minus 0.0". We want this cut out to be, if anything, larger than nominal because if it is smaller than nominal the slider will not clear the slider base and not contact the gland itself.

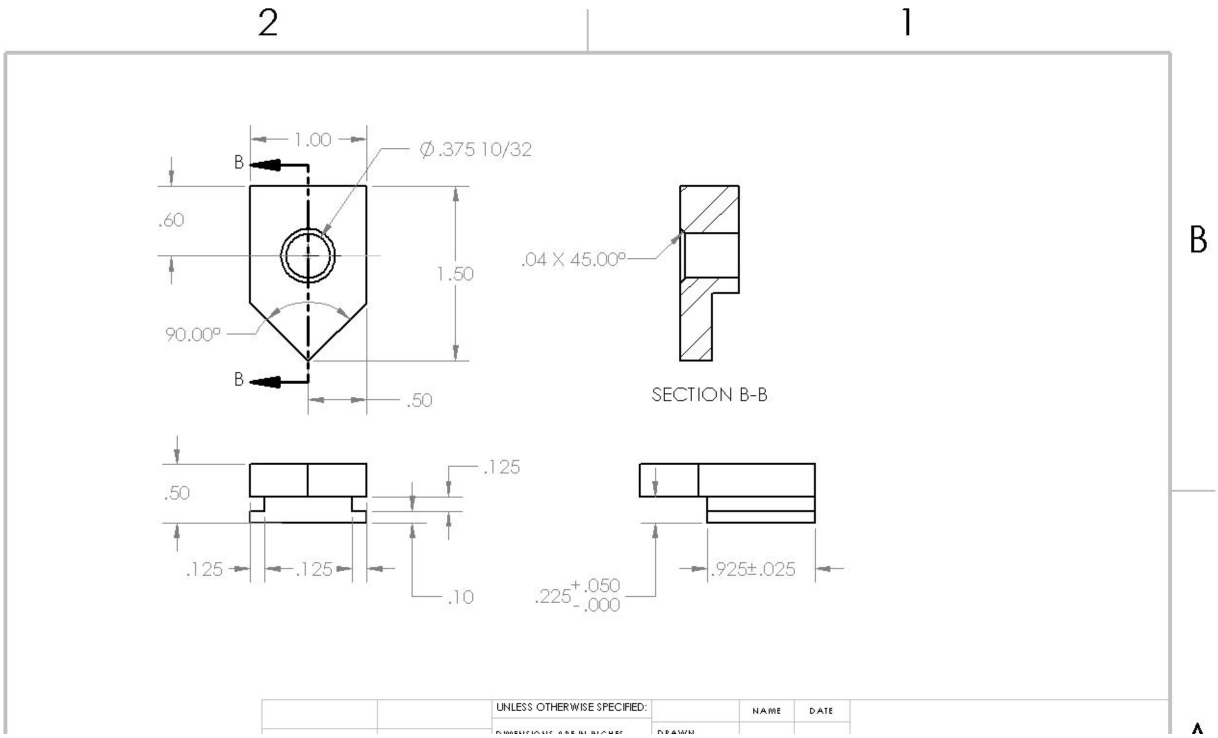


Figure 32: Shop drawing of the slide-lock slider.

With a budget of $5,000 we were able to buy all our materials with significantly less. Below is our Bill of Materials.

Table 3: The bill of materials for the Delta Seal gland fixturing device.

Product	Quantity	Cost per Unit (USD)	Total Cost per Item
Tombstone (Part No. BP07-400400-0650) **CURRENTLY WITHHELD FROM BUDGET**	0	2200	0
Mitee Bite Xpansion Collet (Part No. 31350)	3	118.25	354.75
Stock material for sliding lock channel (33C669 Grainger, A2 tool steel 2x.25in18in)	1	53.82	53.82

Stock material for slider (33C832 Grainger 1.5x.5x18)	1	75.96	75.96
Thumb screw for sliding lock (McMaster Carr 91745A829 package of 10)	1	9.94	9.94
Screws for sliding lock (McMaster Carr 91253A010 package of 50)	1	7.54	7.54
Total Calculated Expense (USD)			502.01

The remainder of the 3D renderings of the parts and assemblies can be found in the appendices section of this report.

10.Engineering Analysis

One issue that Capstone Team 30 encountered when trying to develop a Delta Seal gland fixturing device was creating or purchasing a mechanism that would hold up to the vibrational force of the CNC drill. The gland seals are extremely accurate pieces with very tight tolerances to allow for a premium product, so vibrations or movement of the workpiece could result in crucial deformities or inconsistencies with the gland seals. In order to obtain a baseline value to work with, the team consulted the machinists at MAGSEAL. The force that the clamping mechanism would have to withstand was 50 lbs of force from the CNC drill.

Another important aspect of the clamping device to consider is the material that it is comprised of. The Delta Gland seals are made of stainless steel, so the clamping device had to be softer than stainless steel. The clamping device must yield and subsequently deform before the gland seal does. This is so that the physical integrity of the gland seal remains intact when the clamping device is applied to the gland seal.

The clamping device that Capstone Team 30 chose was an off-the-shelf product known as the Mitee Bite Xpansion collet, which is readily available to order. This product was able to remedy the team's concerns in regard to a clamping force that would negate vibration as well as being comprised of a material that would not affect the integrity of the Delta Seal gland itself.

The Mitee Bite ID Xpansion collet can be turned down on a lathe to fit the inner diameter of both the smaller and larger sized gland seals. Two collets were turned down to 1.272" and 1.934" to fit the smaller and larger sized seals, respectively. Both diameters listed above coincide with the range of material that can be removed from the collet without compromising its structural integrity or the amount of clamping force that it can provide, which is a maximum of 10,000 lbs. This maximum clamping force will easily hold the gland seals without any fear of vibration from the CNC drill.

The material that the Mitee Bite ID Xpansion collet is comprised of is 12L14 steel, which is categorized as a mild steel. This is critical to account for because the 12L14 steel is softer than the stainless steel that the gland seals are comprised of. When the collet is tightened down, the collet will begin to deform before the gland seal will, thus preserving the integrity of the gland seal. Although this steel is considered to be mild and relatively "soft", this product is still durable enough to handle any accidental drops or impacts without being compromised.

Capstone Team 30 took this collet and modified it to have a "quick-change" feature. A SolidWorks file of the part was taken, and a track and a hole were extruded to allow for the 10-32 mounting screws to pass through it. This allows the 10-32 mounting screws to remain within the aluminum plate without having to be completely backed out. Because of this design, the chance of cross threading the aluminum base plate can be completely neglected. The collet can then be twisted, and the mounting screws can be torqued down. An illustration of this design can be seen in Figure 33 below.

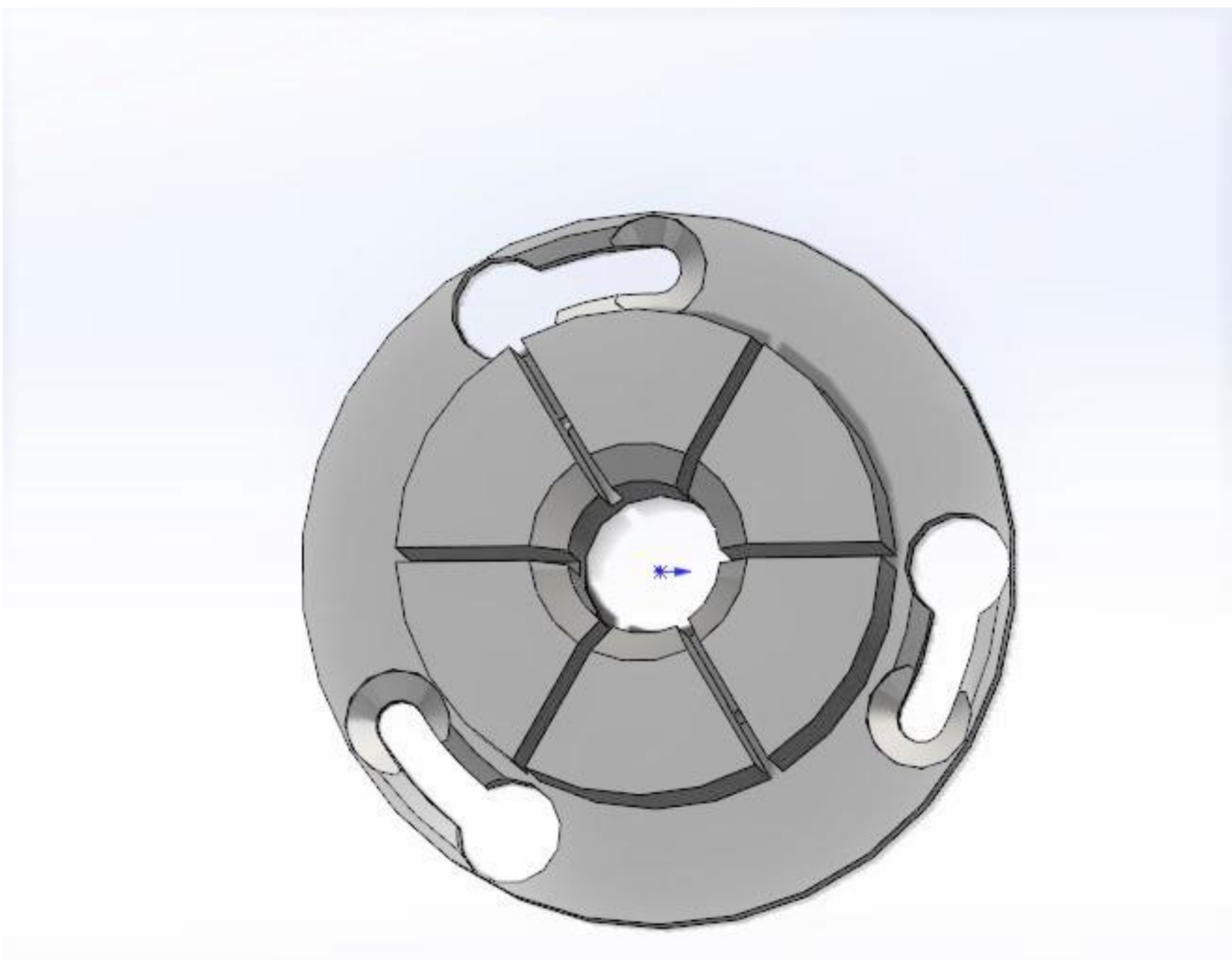


Figure 33: The modified Mitee Bite ID Xpansion collet is shown with the chamfered channel and holes to allow for a quick-change feature.

The quick-change feature allows the customer to easily swap out the modified collets depending on what sized Delta Seal gland is to be machined. However, the area around the pass-through holes and chamfer is very close to the outer edge of the flange diameter, as seen in Figure 33. This was of some concern to the team, since the material at the edge is very thin, and could possibly deform quite easily after repeated use.

The team performed a finite element analysis on this modified collet to be sure that the piece would still be structurally sound with the modifications that were made. The finite element analysis testing was performed using SolidWorks software as seen in Figure 34 and in Figure 35. The yield strength of 12L14 steel was inputted at 427474.95 kPA (62,000 psi), and the 10-32 mounting screws were subjected to a 100 N-m torque (which is equivalent to 73.7562 lb-ft). This torque value was chosen to be much higher than the actual torque spec (60 ft-lbs or 81.3491 N-m) of the mounting screws in order to account for any possible over-torque situations. The collet did exceptionally well when subjected to this torque, with no deformations occurring.

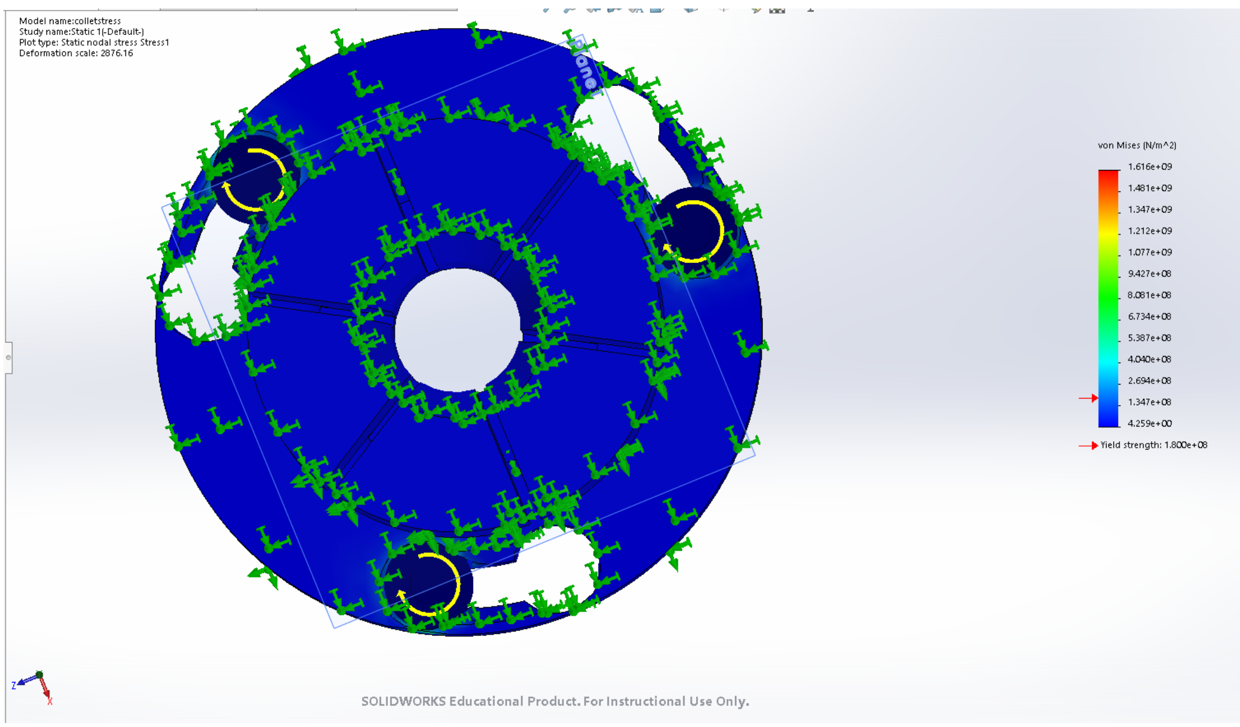


Figure 34: The modified Mitee Bite ID Xpansion collet subjected to a 100 N-m torque from the three 10-32 mounting screws.

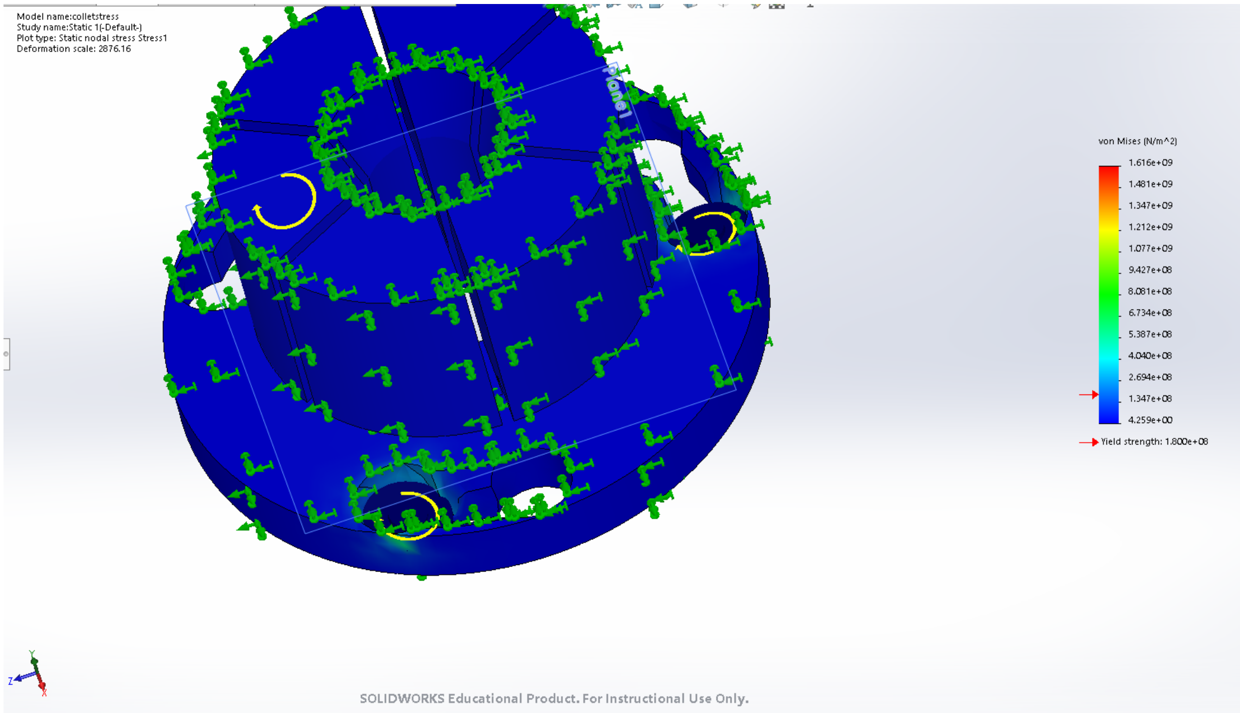


Figure 35: The modified Mitee Bite ID Xpansion collet subjected to a 100 N-m torque from the three 10-32 mounting screws at an alternate angle.

11. Build/Manufacture

With every great concept there is a build story behind it. Armed with an array of A2 tool steel, some 10-32 screws, Mitee-Bite 31350 collets, and a bare 6061 Aluminum plate, it was time to create a real, workable product. This build section will be broken up into the different parts required to create the assembly. Team 30 truly appreciates the help and insight provided by Joe Gomez and Dave Ferreira, as well as Technical Hardfacing and Machining (THM) machinist Kevin Smith. Without these people and their knowledge of effective and efficient manufacturing, Team 30 would have had a great deal more difficulty turning the engineering drawings into physical parts.

To start out, Team 30 picked up our 6061 Aluminum plate from THM in Attleboro Mass. Upon receiving the 12”x24”x2” plate, machinist Kevin Smith informed us that since the plate was created from a process called extrusion, the plate would need to be “faced”. Facing removes the curves and impurities that occur when manufacturing occurs. To face a part, it must be put on a mill and have a wide end mill attached. This end mill differs from the typical cutting end mill in a few different ways. First, is the sheer cutting size of a facing end mill, these mills can range in sizes comparable to a normal cutting end mill (0.5” diameter) to about 13” in diameter. They also differ in construction from the normal end mill. The typical facing end mill is of modular construction. This means that the cutting tips are removable and replaceable to preserve the service life of this expensive part. With the twist of an Allen screw, a tired, old facing end mill can be made to cut like new again. A typical 4.000” facing end mill runs about $1,000 depending on needs and features, such as cut style and number of cutters on the tool. At first, Team 30 took the un-faced plate to the URI machine shop with hopes of having the process done there, and were informed that the plate was too large to be faced on the school's aging CNC machine. The aluminum plate was then returned to THM, as they are well equipped for this task. While the plate was being faced at THM, the holes for mounting the plate to the angle cast were drilled as well as the holes for alignment pins to ensure that the plate is square and true when mounted for machining gland seals. Team 30 picked up the faced plate a few days later, as Joe Gomez of the URI machine shop said it was possible to machine the slider and Mitee-Bite pockets on the school's CNC machine, however, he had to attend to making a box for the chemistry department. Team 30, in the meantime, started on the construction of other pieces to the assembly. As time went on, Joe confessed to the team that due to the difficulty of the lack of a cohesive design for the box that the chemistry box requested he make that he would not be able to make the cuts to the aluminum plate. Team 30 then contacted THM to ask them if they had the time machine the plate for the pockets in order to fix a single gland seal vs. the original plan for three glands. THM agreed to machining provisions for a single gland, and asked if the Team would like to be present for this process. Team 30 agreed and actively participated in the machining of the aluminum plate. Once again, we were paired up with experienced machinist Kevin Smith. Kevin lent us some excellent tips for designing parts to be manufactured efficiently, such as rounding off corners for use with wider path end mills, the proper tolerances for making the Mitee-Bite fit, but be able to be removed with ease, and ways to polish off a design to make it easier for the machinist to understand and create. Together with Kevin, the design was modified slightly to reduce machining time and complexity. The Solidworks part file was then converted to a Mastercam file, which was opened by the program and converted the design to G-code. G-code is the language of operation that CNC machines work with in order to find the correct orientation, depth, and cutting speed. Kevin then loaded the proper end mills and drill bits into the machine and the plate was clamped and zeroed on the machine. After clearing a few error messages, the Fanuc controls take care of the hard work. The workpiece is then flooded with low pressure machine coolant as the end mill shapes the plate and bores the holes for the 10-32 screws as well as the pass through 5/8-11 tapered screw for the Mitee-Bite. After the CNC finished with the cuts, one of the collets was test fitted to ensure the process was successful. Next, the 3 securement holes for the collet base and the 12 securement holes for the sliders were tapped using a hand tap and tapping oil. After that, the final piece to this puzzle was the addition of threads to the hole for the 5/8-11 tapered screw for the collet. This screw is responsible for the holding for the gland to the collet by expanding the collet when tightened. Since this screw and threads will be regularly seeing in excess of 100 ft-lbs of torque, a Helicoil is required for strength and durability. In order to install a Helicoil of this size, the hole must be 21/32" in diameter. This was done by the CNC, as it was designed with this in mind. Next, the hole was tapped using the supplied tap with the kit that is especially for creating a path to add threads. After that, the threads were dressed on the installation tool, and spun into the tapped hole until the tool bottoms out, as that is the correct range of thread engagement with the tapered collet bolt.

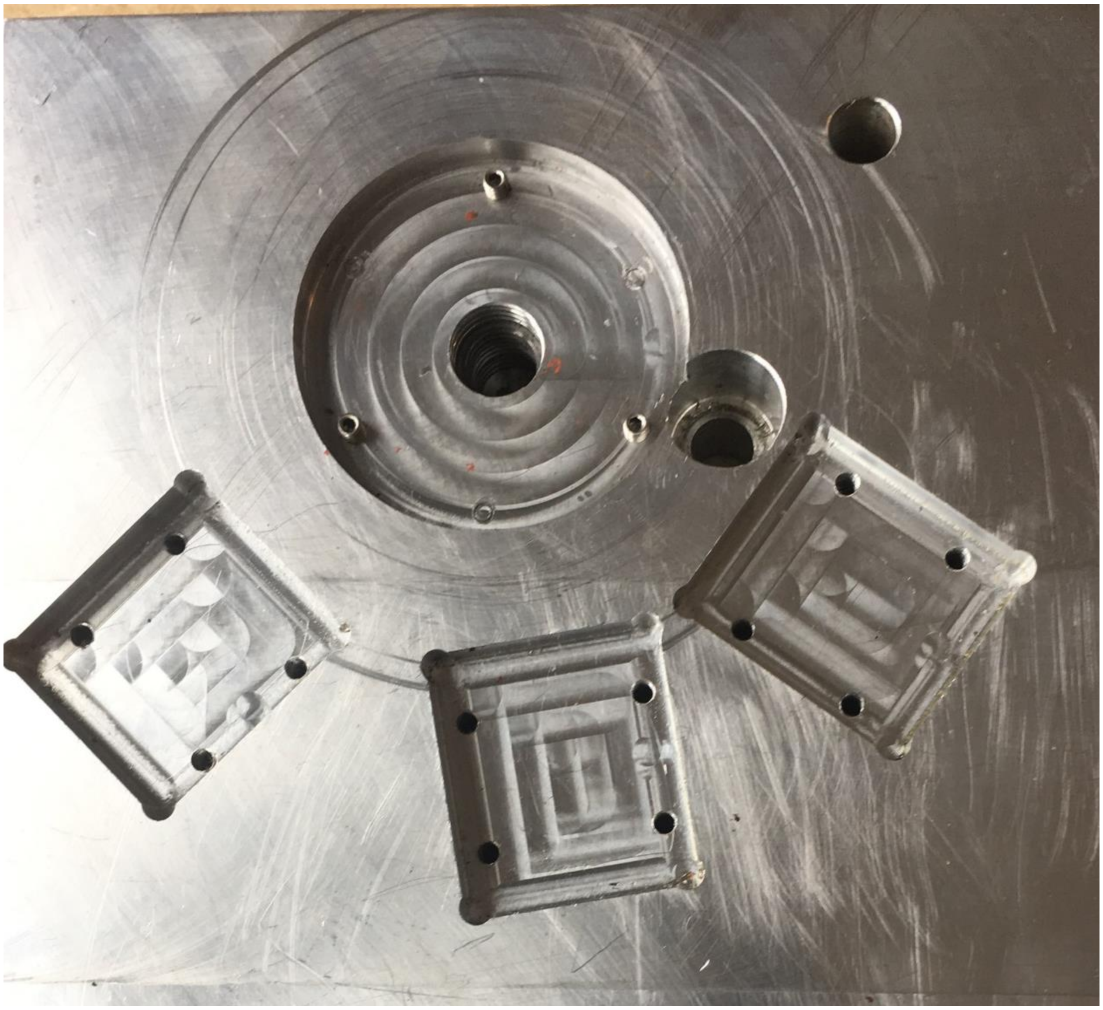


Figure 36: Detailed view of machined pockets on aluminum plate.

The next big item to be tailored to the needs of the project was the Mitee-Bite #31350 ID Xpansion Collet. Out of the box, the collets are 2.000” in diameter, and must be turned down to the proper size for the gland. In order to do this, the collet must be tightened with the supplied nut and tapered screw to expand the piece. Next, the inside of the diameter of the part it will be fit to must be measured. With this measurement, add 0.002”-0.003”, and that is the amount the collet will be turned down to. To remove the material safely and effectively, the URI machine shop’s engine lathe was utilized. In order to properly affixing these collets in the lathe, two people are required because a set of machining parallels were required to space the collet from the back of the lathe head. This made it necessary for one person to hold the parallels and the collet and the other to tighten the jaws of the lathe. A maximum of 0.050” was taken off each pass. The single seal collet was machined down to 1.940” and the collet for the double seal was turned down to 1.278”. The leading edges were beveled with a file while the pieces were still on the lathe. After the test fitting the gland seals to collets, they were sanded on the lathe with 100 and 180 sandpaper. This ensures a smooth action for removing and adding the glands to the system. After this, the collet was drilled and tapped for three 10-32 screws. These screws are “jacking” screws to assist the removal of a stuck collet in the aluminum plate. 6061 aluminum changes noticeably with temperature, so this is a necessary precaution to take to preserve the quick change aspect of the system. Once these holes were drilled, tapped, and deburred, the collet was reversed on the lathe with the base side outside of the jaws. The circumference of the base was run down lightly with a file to remove imperfections and help ease the installation and removal of the collet without interference from paint or bumps.

Figure 37: Double seal collet top view.

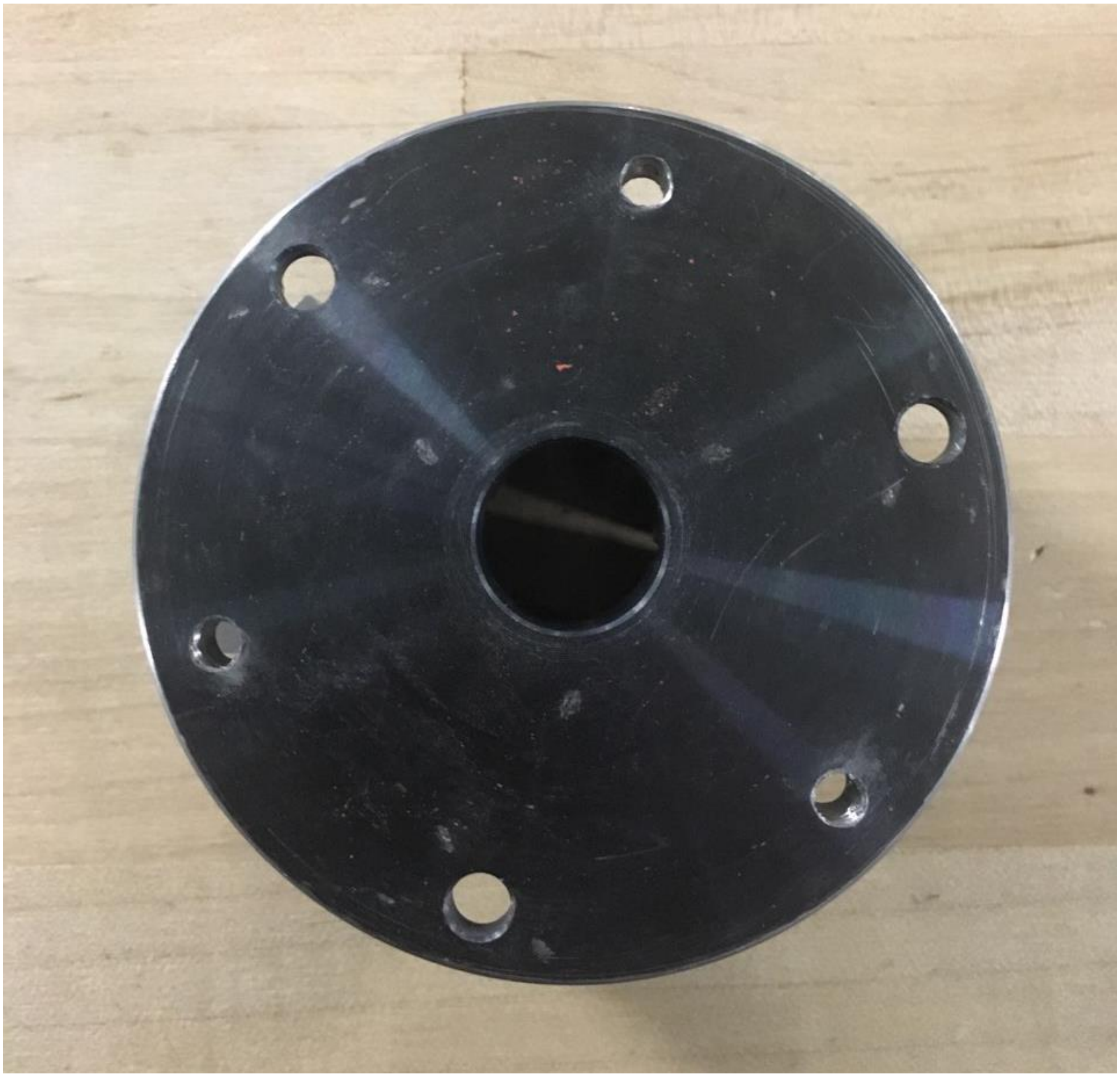


Figure 38: Finished collet bottom view.

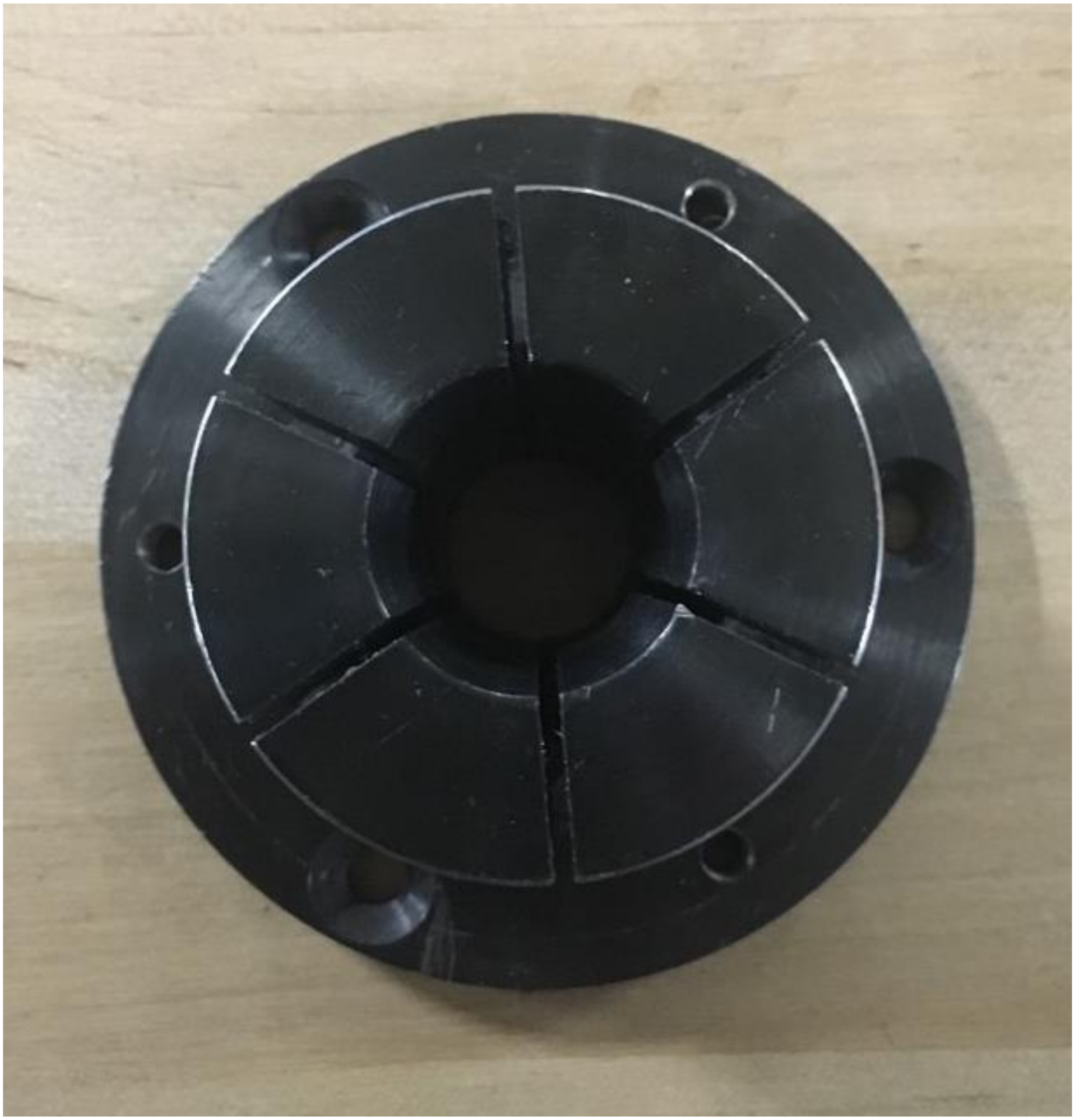


Figure 39: Single seal collet top view.

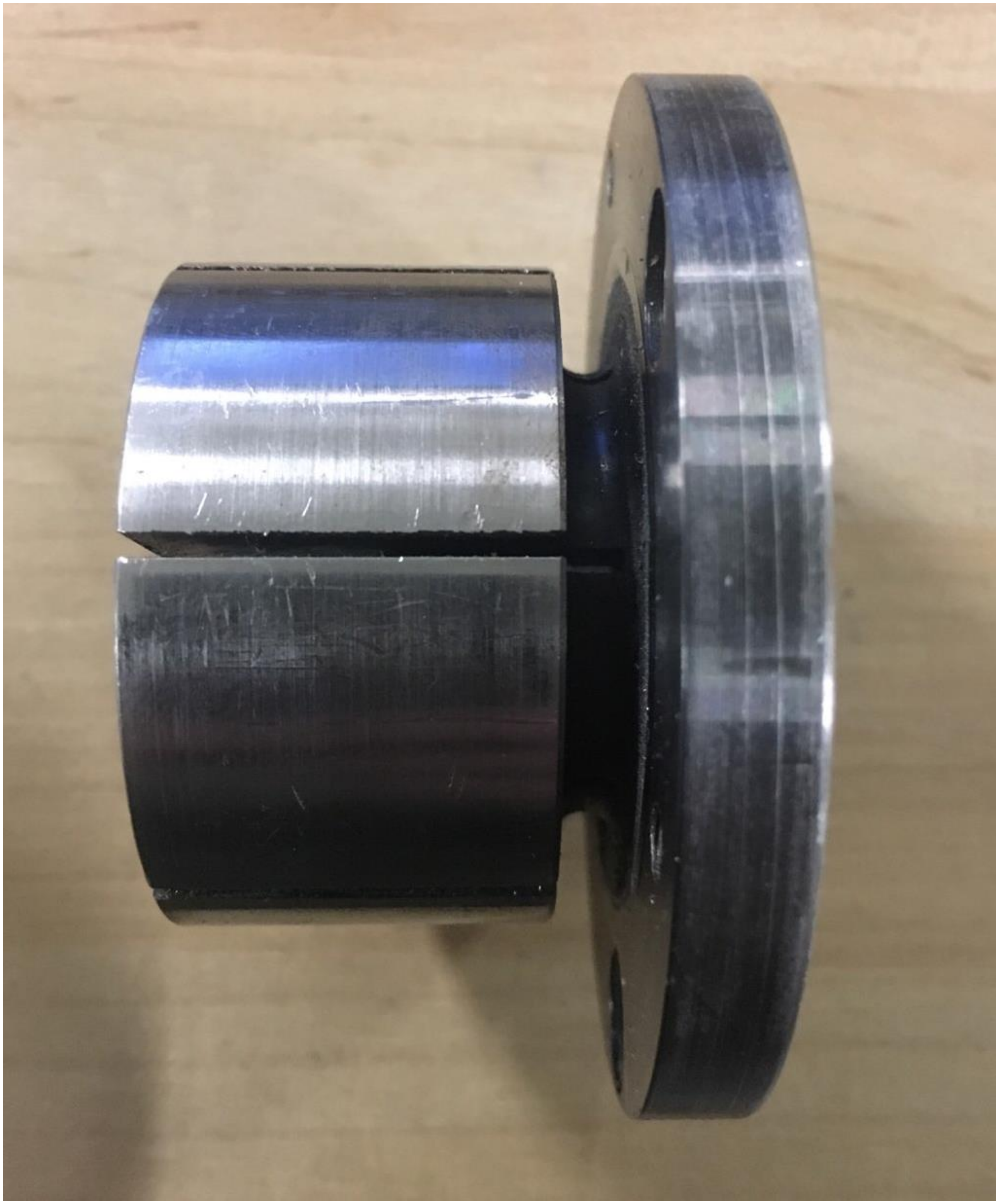


Figure 40: Single seal collet side view.

Once the collets were tailored to the two different sizes of gland that we were given to work with, it was time to work on the sliders. The slider assembly can be broken into three basic components: slider, slider base, and slider plate. These items are designed to work in unison to create a comprehensive and simple way to orient the gland for drilling, tapping, and machining. In order to create these, Team 30 ordered two different sizes of A2 tool steel. Our sponsor recommended that we use tool steel for this portion of the process due to its resistance to wear and the ability to yield the same location if machined correctly. MAGSEAL ordered us two 18" sections of A2 for the creation of this project. One size is 2"x .25" x 18", for the base and plates and the other is 1.5"x.5"x18" for the creation of the sliders. To start, the slider stock was divided up into sections that were about a tenth of an inch wider than necessary. This ensured that there was enough material on the side to mill it true. The stock was cut with the URI machine shop's band saw. After creating 4 of these rectangular blocks, they were taken to the JET knee mill. This machine has the ability to remove material in a very precise fashion that will leave a nice surface finish depending on the speeds and feeds set by the operator. The rectangular blocks were secured into the machine's vice, and an edge finder was used to help set up the machine's digital readout. Next, the end mill was selected. In order to efficiently cut and mill tool steel, a carbide end mill is preferred. For this instance, Joe Gomez graciously lent the Team his carbide 0.475" 4 flute end mill. This allowed us to remove material precisely and at a rate much quicker than a non-carbide end mill. When a regular, non-carbide end mill is used on this material, an extremely slow feed rate is required to keep the tool from getting damaged or from the material being work hardened from the heat from the milling action. Once the width of the slider was dialed in and all sides of the block were deemed square, the pointed tip was machined into the block. In order to obtain the desired angle Joe Gomez allowed Team 30 to use his adjustable angle vise and Bridgeport knee mill. The proper cutting angle was obtained by using a dial indicator and his personal 45 degree block, which took him 5 years to make. Once the block and indicator relayed to the operator that it was zeroed, the rectangular blocks were machined to a point using the same end mill as the previous step. After the tips of the blocks were finished, the channel for the slider plate was cut. To do this, a 0.125" regular end mill was utilized. This piece came from machinist Dave Ferreira, who also adjusted the feed speed of the mill for this cutter. A water-based cutting fluid was also provided to dissipate heat from the cut. The notches for the slider plate were designed square, 0.125" deep, and 0.125" wide. Material from this cut was removed at a rate of 0.010" per pass. In addition, these channels were cleaned up and tested for fit with the slider plates, numbering which ones fit the proper channels. Next, the over-travel bite was milled. This extra 0.575" milled off of the bottom lengthwise allowed for the slider to contact multiple sizes of gland. The next step to be done to the slider would have been to drill and tap for the 10-32 thumb screw, but Team 30 did not make it to that step. While the sliders were being milled, Team 30 started cutting the other piece of stock to 0.100" over the specified width of 1.750" for the slider bases. These pieces were then milled square using the same method as the slider blocks, use the back of the vise as a guide, check both ends of the cut for the same measurements, and adjust accordingly. After these pieces were deemed square, Team 30 milled the center sliding track out of this base plate. The Team did not finish machining these pieces, as we ran out of time before the four holes for securement could be drilled and the slider track be machined down to the proper depth. The last piece of the slider assembly are the slider plates. These plates engage the side of the slider to keep it located and moving smoothly. To start out, a 3.500" section was cut from the 2"x.25"x18" A2 stock. This section was then taken to the JET knee mill and machined down to 0.125” in order to fit the grove on the side of the slider. The milled piece was then taken back to the band saw and cut to widths slightly over 0.475” (results varied as cutting these small pieces was difficult). These pieces were taken back to the mill to slim them down to the correct measurement while keeping the sides of the pieces square for accurate gland engagement as well as a smooth and uniform slider contact surface.

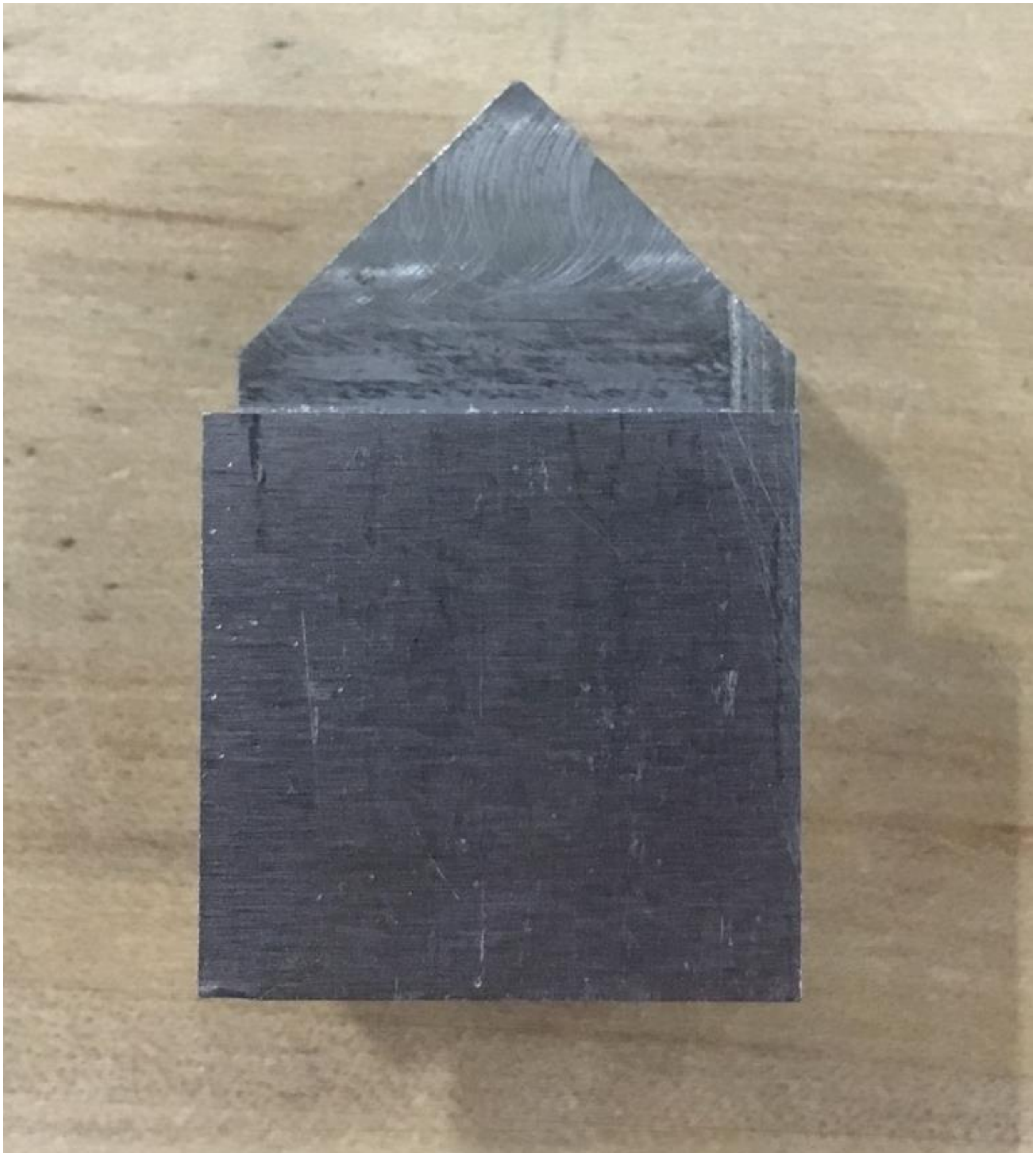


Figure 41: Slider bottom view.

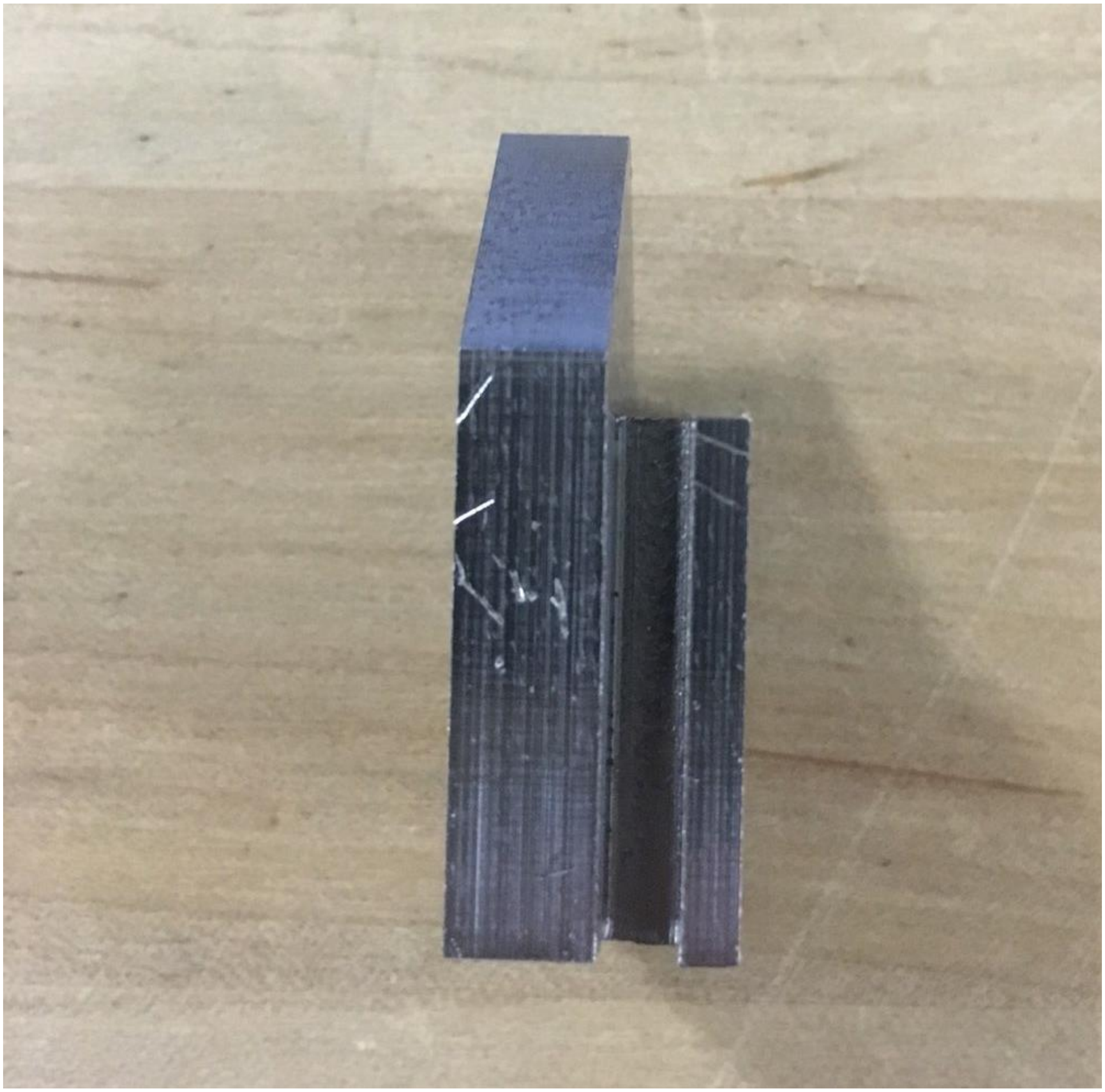


Figure 42: Slider side view.

Figure 43: Slider top view.

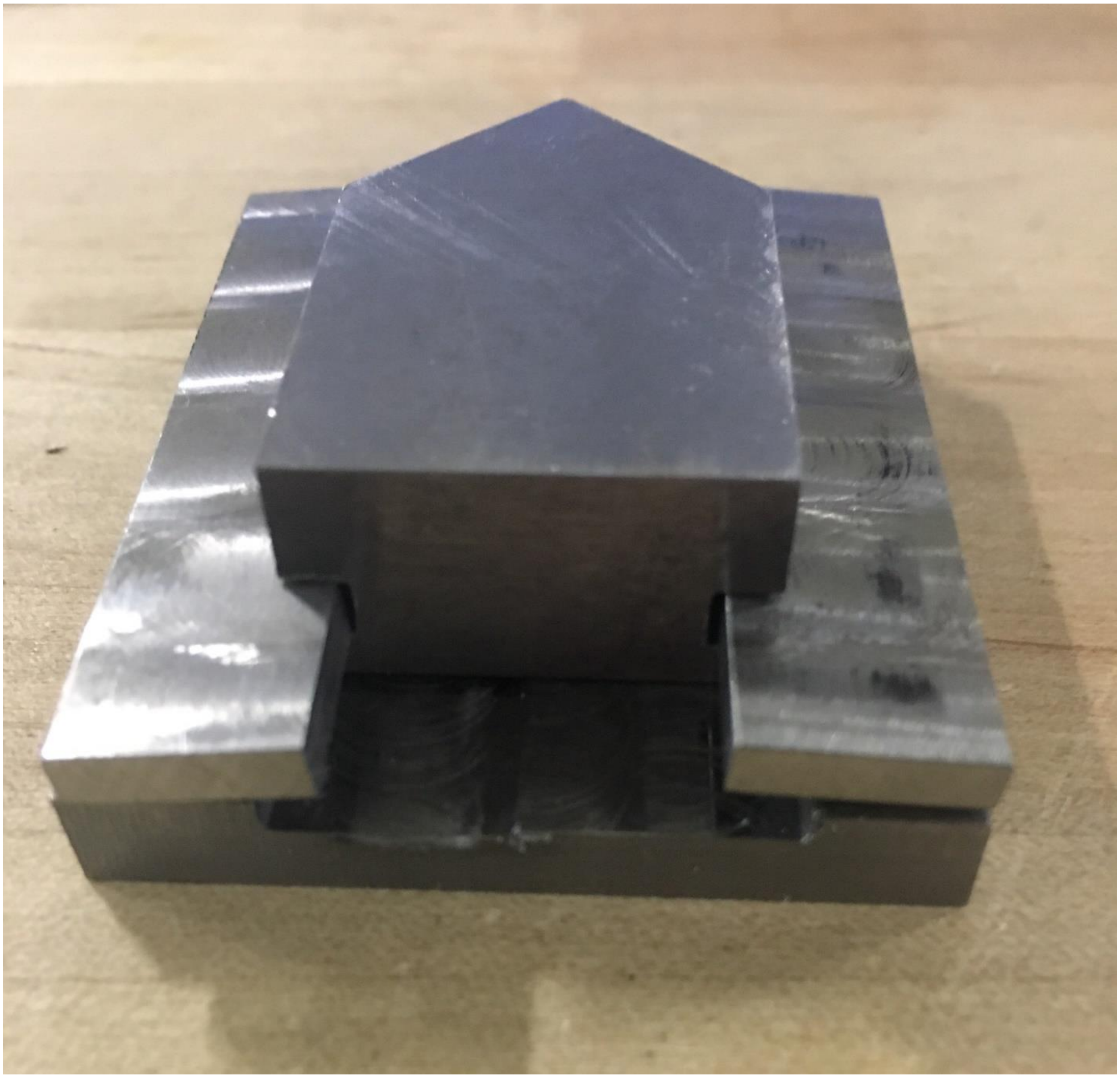


Figure 44: Semi-completed slider assembly.

Team 30 was unable to create a final assembly of the slider system, however there was plenty of lessons learned in how to efficiently machine items like the ones for our capstone project. If the Team were to mass produce this system there are a few definite changes that would have to be made to decrease the time and tooling required to get our product ready. The first change that would be made in the name of efficiency and savings would be the use of 0.125 stock in order to reduce the amount of milling required. The beauty of the A2 that was purchased is that is a precision surface out of the box. If the manufacturing process was able to go without milling part faces, there would be at least 7 hours of machining time saved. In addition to this, the use of a CNC to cut the sliding channels in the slider base would save another 3 hours of time. Team 30 learned that the best use of resources is to find the material closest in size to the final product while still keeping in mind the machining process and how that can change the material. Another key consideration for a higher production run would be the use of a laser cutter to cut the slider, base, and slider plate due to the high degree of accuracy they are able to attain with little to no operator attention needed. While Team 30's design is not intended for mass production these are some steps that would make the manufacture of a working product easier. This product is designed specifically for in-house use at THM in conjunction with their Kitamura MyCenter HY-400, so only one copy will be produced for use on this machine if THM decides to move forward with this design. In addition due to the one-off nature of this project, a model of the manufacturing system design is not necessary. It will be created with resources and machine tools found within the shop, which they are more than well equipped to do so with. THM has multiple CNC machines, lathes, knee mills, saws, drill presses, and other associated tools to recreate what Team 30 has designed with the Team's drawings and files once shared with the facility at the end of the school year.

12.Testing

Our team was unable to finish manufacturing our device and only a few tests were possible to run. The Testing Matrix of Capstone Team 30 is found below in Table 4.

Table 4: The Test Matrix developed by Capstone Team 30.

Subject	What to Test	Test Parameters	Results	Planned Resolutions
Collet base flange bolts	Do they hold up to machining? Twisting/Shearing? Measure bottom of collet as well as distance between bolt heads.	Tighten collet and gland down, machine, and measure as stated in the what to test box.	N/A Design has been modified to use studs.	Resolved
Collet Gripping	Does it grip the part successfully?	Fasten the part into the collet and machine flush and drain ports.	Collet grips part securely; no machining has been done.	Will not be able to machine glands to test this fully.
Collet Durability	Does the collet have marks from gripping? Before and after photos will be used for evidence.	Take photos of collet contact surface, machine gland, remove and inspect.	Slight scratching from high contact spots on collet.	Will not be able to machine glands to test this fully.
Load Time	Can the collets be changed with ease? Time?	Time the load time from collet off the plate to secured gland.	14.75 seconds	None

Unload Time	Can the collets be changed with ease? Time?	Time the unload time from collet off the plate.	18.06 seconds	Have a proper Allen Key socket
Collet Main Bolt Head	Is there any damage from tightening the bolt to 224 ft-lbs? Look for evidence of rounding, photos before and after, marring, etc.	Tighten the center bolt.	Slight paint bolt paint removal.	None, the part is still usable.
Aluminum Plate	Any damage to the plate in areas of contact? Photos of contact areas before and after.	Secure all fixtures to aluminium plate, machine part, take off all fixtures and inspect as well take photos before and after.	There are cosmetic scratches from rotating glands.	There will be machine cutting fluid on the plate to act as a lubricant. Other than that, none.
Slider	How long does it take for each change in position? Do the sliders move on their own during machining? Take measurements.	Time each position change as well as measure the distance from the end of the slider track to the base of the slider to ensure it stays in the same spot.	40.1 seconds through all three positions	Theoretical tests; sliders not fully machined.
Slider Components	Do the slider components interact well with each other? Does the thumb screw lock the location?	Measure locations of locked slider before and after machining.	N/A	Sliders not fully machined
Slider Durability	Any signs of slider wear? Where? Take pictures before and after.	Take photos of slider contact surface before and after for comparison.	No markings observed.	None
Slider Contact	Does it contact the ears of the gland in a way that does not	Take photos of the gland contact surfaces before and after for comparison.	No damage or scratching on glands observed.	None

	damage it? Check for signs of marring.			
Slider Attachment Bolts	Do the bolts hold up to use? Bending? Twisting? Measure.	Secure all attachments, machine the part, remove pieces and inspect for signs of damage.	N/A	Did not complete machining of sliders.
Slider Orientation	Do the sliders have proper orientation?	Rotate gland in each orientation. Is the drilling surface parallel to the top face of the place?	Two of three sliders are in correct orientation.	Proper angles were not provided. Therefore, proper angles will be obtained and implemented on future plates.

The three tests we ran were Load Time, Unload Time, and the Slider test. These were the only tests we could run. The load time test was run to see how long it would take to place the collet in the aluminum base plate, put the gland onto the collet, turn the gland to its proper angle, and tighten the collet down. When we timed this test it took roughly 14 seconds to perform. This test is important because the whole purpose of this device is to reduce the amount of time it takes the operator to produce glands. We feel comfortable in how this test was performed and with the results it produced.

The unload time test was similar to the load test. We wanted to know how long it took to loosen the collet and slider, and remove the gland. This took roughly 18 seconds to perform. However, at the time we did not have the proper drill size to loosen the collet. This is why it took longer than the load time. We are confident that with the proper Allen key socket the operator could remove the gland much quicker.

The third timed test was to see how long it would take to cycle the gland through all three slider positions. This took roughly 40 seconds through all three positions. We believe that the operator could perform this process quicker because, like the unload test, we did not have the proper key size at the time of the test.

Since we could not fully manufacture and build our device we were unable to put this into the CNC machine to machine the glands. This meant that most other results could only be observed. The cosmetic scratches are a good example for these types of tests; we could observe cosmetic differences on the aluminum base plate as well as the sliders themselves. We believe and are confident that all scratches and markings are only cosmetic and would not hinder any machining process.

One of the biggest failures is that one of the orientations of the sliders is incorrect. This means that one of the angular positions of the gland will not allow the operator to machine one of the required holes. This issue most likely stemmed from the fact that we measured this angles ourselves. In hindsight we should have gotten the proper dimensions from MAGSEAL.

Since we designed and partially built this for in-house use at MAGSEAL we did not feel the need to consider any official standards. We also did not consider any of these standards because any part of this device that would require these standards were already in use at this facility. This means that any standards were already taken into account. For example, the weight of the aluminum plate would need to be taken into account for certain OSHA standards. Since this aluminum plate is already a part used at this facility we did not need to account for any of these standards.

Table 5: the table below features the tests that Team 30 performed.

Load Test No. 1	
MCE 402 Team #30	Record of Individual Test
Name of Tester	Jacob Farnham, John Cocce
Date of Test	05/01/2019
Time of Test	4:20 PM
Description of Test	Load Time
Test Parameters	Timed the process of loading the collet onto the aluminum plate an secured a gland seal to the collet.
Results of Test	14.75 seconds
Resolution if Needed	None
Unload Test No. 1	
MCE 402 Team #30	Record of Individual Test
Name of Tester	Jacob Farnham, John Cocce
Date of Test	05/01/2019
Time of Test	4:55 PM
Description of Test	Unload Time
Test Parameters	Time the unload time from collet off the plate.

Results of Test	18.06 seconds
Resolution if Needed	Have a proper Allen Key socket
Unload Test No. 2	
MCE 402 Team #30	Record of Individual Test
Name of Tester	Jacob Farnham, John Cocce
Date of Test	05/01/2019
Time of Test	5:10 PM
Description of Test	Unload Time
Test Parameters	Time taken to change the orientation of the gland seal from one slider to another
Results of Test	40.14 seconds
Resolution if Needed	Theoretical tests; sliders not fully machined.

13. Redesign

Based on your testing procedures, did you identify a need to redesign your product? If so, present your final detailed design. If the constraints of time did not allow you to implement your redesign plan, i.e. re-building your prototype, present your final paper design. Provide detailed recommendations for future design teams to improve on your design based on what you have learned.

Most of the redesign aspects happened during the machining and fabrication process. Initially we had a twist lock mechanism planned to be machined into the collet. However, after learning about further design specification changes we decided to not use this mechanism. We did implement studs to improve the release of the collet from the aluminum plate. This proved much simpler to fabricate. The twist lock mechanism would have taken a lot of patience and skill to machine. The precision required for the twist lock system would have also needed to be much higher.

While the sliders were being machined and put together we realized that it did not clear the base plate and the tip of the slider would contact the socket wall. To fix this we cut out a section on the bottom of the slider to allow the top have to slide across the top of the aluminum plate and contact the ears of the glands, as they were designed to do.

While machining the cutouts in the aluminum plate, the machinist at MAGSEAL showed us a flaw in our design. Our design, as it was, was technically impossible to make with the machines available. In the design we had perfect rectangles with sharp corners which are not only extremely difficult to machine but would also make it very difficult to insert the slider mechanisms. The machinist showed us that if we design reliefs in the corners of the sockets it would be possible to machine and allow the slider mechanisms to be implemented. The reliefs were fillets which took the place of the sharp corners.

Since we did not completely finish making our device we were only able to perform a few of the expected tests we had planned. This also meant that we could not apply any potential new designs based off of the results of the tests we performed. All of our redesigns occurred in the machining process and as our project definition continually changed.

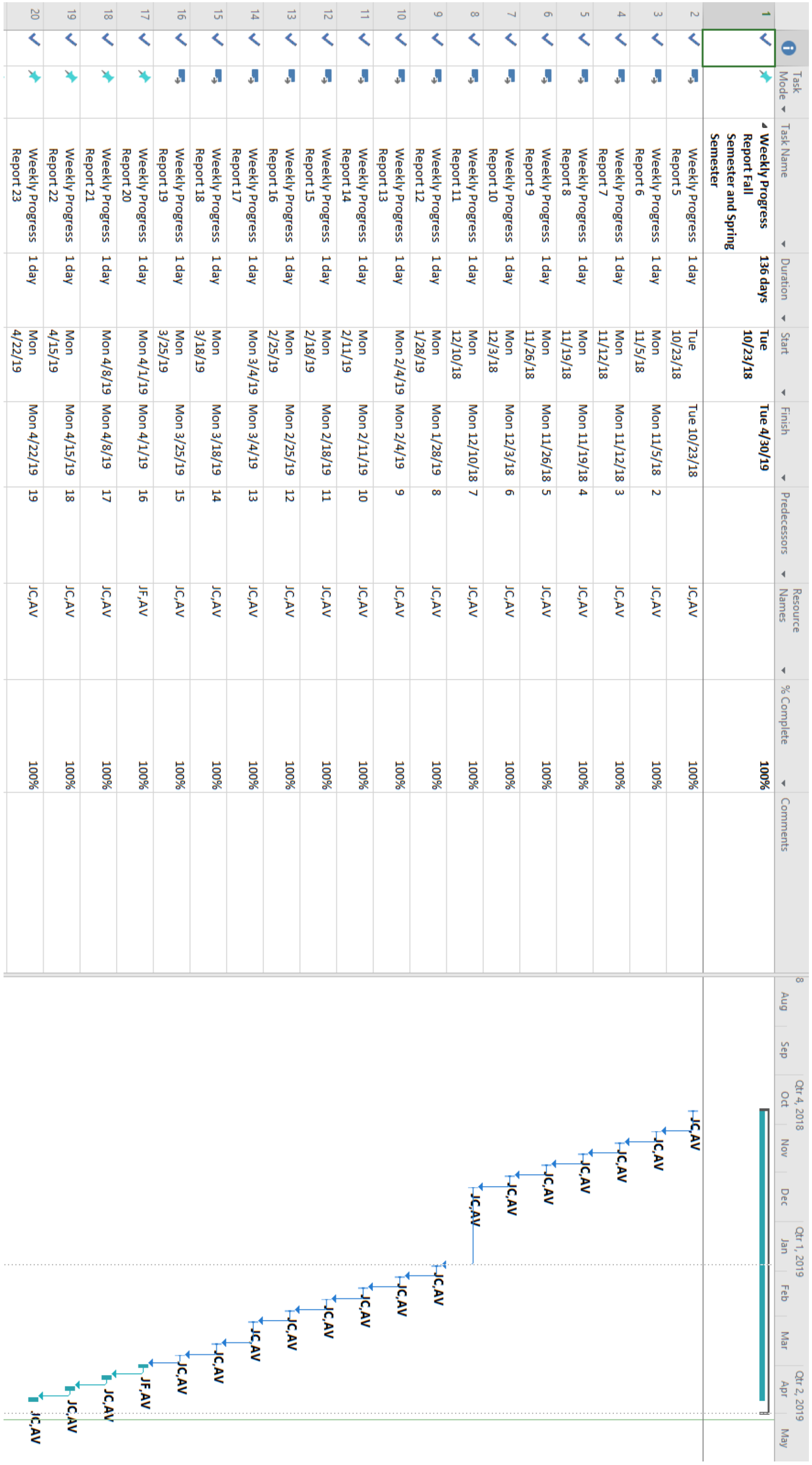
Future recommendations on the project would be to utilize the 3-D printer. Designing a model in SolidWorks and on paper is helpful as a preliminary visualization. If we were to use the 3-D printer we would have seen the discrepancies in our designs sooner and would have saved time in the machining process. Using rapid prototyping also would have allowed us to have solid models of other designs that we could have used or even evolved into something that we could have designed into the final design.

If our group were to do this project over again we would like to be in more direct contact with the machinist or machinists who machine the glands. Knowing their needs more personally and understanding the process fully would have allowed us to design our product with their needs in mind. Instead we created a design that was an amalgamation of separate designs. We believe that our product could have been more cohesive if we were to work closely with the machinist.

Similarly, we took it upon ourselves to measure certain aspects of the glands that were not accurately conveyed to our design. We realized this mistake after we machined the aluminum plate. This could have been avoided if we obtained all accurate design specifications prior to any permanent work that was done.

14. Project Planning

In order to keep the project progressing at a linear rate throughout the semester it was necessary to plan steps in Microsoft Project and record the progress of these plans with an associated percentage of completeness. Capstone Team 30 also noted the team members involved in each recorded tasks. Below is our Gantt chart as of the writing of this report. Some notable sections are the various meetings with our sponsors, completed weekly progress reports, and the scheduling of presentations, reviews, and other semester tasks. The Gantt chart was useful to see what the future held and how the Team could successfully move forward to complete our goals in a timely manner. While the team did run into some shipping delays with our project, the progress made was immense, and generally on time when the issues were within our control. Any issues with our project and scheduling were recorded in the Weekly Progress Report and read by the teaching assistants. Our professionalism with these reports is reflected with the grades, as all of the spring semesters progress reports received a perfect grade, and the updated Gantt chart is a piece of this. Attached below is the project plan for the entire year, split into the progress reports, first semester, and second semester. The project plan is split up into these groups strictly for ease of reading the plan, as when the whole plan is attached as a single image it is extremely hard to read. Access to the Microsoft Project file can be found in Capstone Team 30's Project Management Folder. The chart is divides tasks starting by name, duration, start date, finish date, predecessors, resource names, % complete, and comments. In our Gantt chart, the resource names has three different abbreviations for the team members involved. AV represents Anthony Vessella, JC represents John Cocce, and JF represents Jake Farnham.



	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names	% Complete	Comments
1		**Weekly Progress Report Fall Semester and Spring Semester**	**136 days**	**Tue 10/23/18**	**Tue 4/30/19**			**100%**	
2		Weekly Progress Report 5	1 day	Tue 10/23/18	Tue 10/23/18		JC,AV	100%	
3		Weekly Progress Report 6	1 day	Mon 11/5/18	Mon 11/5/18	2	JC,AV	100%	
4		Weekly Progress Report 7	1 day	Mon 11/12/18	Mon 11/12/18	3	JC,AV	100%	
5		Weekly Progress Report 8	1 day	Mon 11/19/18	Mon 11/19/18	4	JC,AV	100%	
6		Weekly Progress Report 9	1 day	Mon 11/26/18	Mon 11/26/18	5	JC,AV	100%	
7		Weekly Progress Report 10	1 day	Mon 12/3/18	Mon 12/3/18	6	JC,AV	100%	
8		Weekly Progress Report 11	1 day	Mon 12/10/18	Mon 12/10/18	7	JC,AV	100%	
9		Weekly Progress Report 12	1 day	Mon 1/28/19	Mon 1/28/19	8	JC,AV	100%	
10		Weekly Progress Report 13	1 day	Mon 2/4/19	Mon 2/4/19	9	JC,AV	100%	
11		Weekly Progress Report 14	1 day	Mon 2/11/19	Mon 2/11/19	10	JC,AV	100%	
12		Weekly Progress Report 15	1 day	Mon 2/18/19	Mon 2/18/19	11	JC,AV	100%	
13		Weekly Progress Report 16	1 day	Mon 2/25/19	Mon 2/25/19	12	JC,AV	100%	
14		Weekly Progress Report 17	1 day	Mon 3/4/19	Mon 3/4/19	13	JC,AV	100%	
15		Weekly Progress Report 18	1 day	Mon 3/18/19	Mon 3/18/19	14	JC,AV	100%	
16		Weekly Progress Report 19	1 day	Mon 3/25/19	Mon 3/25/19	15	JC,AV	100%	
17		Weekly Progress Report 20	1 day	Mon 4/1/19	Mon 4/1/19	16	JF,AV	100%	
18		Weekly Progress Report 21	1 day	Mon 4/8/19	Mon 4/8/19	17	JC,AV	100%	
19		Weekly Progress Report 22	1 day	Mon 4/15/19	Mon 4/15/19	18	JC,AV	100%	
20		Weekly Progress Report 23	1 day	Mon 4/22/19	Mon 4/22/19	19	JC,AV	100%	

Figure 45: Project Plan detailing weekly progress reports.

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names	% Complete	Comments
21	**Meeting w/ Dennis**	**13 days**	**Tue 10/23/1**	**Thu 11/8/18**			**91%**	
22	Prepare Best Ideas	4 days	Tue 10/23/18	Fri 10/26/18		JC,AV,JF	85%	
23	Possible SW designs	7 days	Mon 10/29/18	Tue 11/6/18	22	JF	90%	
24	Meeting with Elio Manzi regarding project direction	1 day	Thu 11/1/18	Thu 11/1/18		AV,JC	100%	
25	Questions	1 day	Fri 11/2/18	Fri 11/2/18	23	JC,AV,JF	100%	
26	Meeting with Dennis scheduled	1 day	Mon 11/5/18	Mon 11/5/18	25	JC,AV,JF	100%	
27	Meeting with Dennis and Jared at THM	1 day	Thu 11/8/18	Thu 11/8/18	26	JC,AV,JF	100%	
28	**Team Presentation**	**3 days**	**Fri 10/26/18**	**Tue 10/30/18**			**67%**	
29	Presentation preperation	2 days	Fri 10/26/18	Mon 10/29/18		JC,AV,JF	50%	
30	Presentation Day	1 day	Tue 10/30/18	Tue 10/30/18	29	JC,AV,JF	100%	
31								
32	**Proof Of Concept**	**20 days**	**Thu 11/8/18**	**Wed 12/5/18**			**89%**	
33	Meeting With THM regarding ideas	1 day	Thu 11/8/18	Thu 11/8/18		JC,AV,JF	100%	
34	Research possible componenets	4 days	Tue 11/13/18	Fri 11/16/18		JC,AV,JF	90%	
35	Solidworks	5 days	Wed 11/7/18	Tue 11/13/18	23	JF	90%	
36	Discuss ideas as a team	14 days	Thu 11/8/18	Tue 11/27/18		JC,AV,JF	95%	
37	Fabrication of Prototype	7 days	Sat 11/17/18	Tue 11/27/18	34	JC,AV	85%	
38	Finalize and Test Prototype	6 days	Tue 11/27/18	Wed 12/5/18	37	JC,AV,JF	85%	
39	Discussion of Ideas	1 day	Tue 11/13/18	Tue 11/13/18		JC,AV,JF	100%	
40	Presentation Preparation	4 days	Wed 11/28/18	Mon 12/3/18		JC,AV,JF	75%	
41	Presentation	1 day	Tue 12/4/18	Tue 12/4/18	40	JC,AV,JF	100%	
42	**Semester Report**	**10 days**	**Tue 12/4/18**	**Mon 12/17/18**			**97%**	
43	Journals	10 days	Tue 12/4/18	Mon 12/17/18		JC,AV,JF	90%	
44	Binder	10 days	Tue 12/4/18	Mon 12/17/18		JC,AV,JF	100%	
45	Writeup	10 days	Tue 12/4/18	Mon 12/17/18		JC,AV,JF	100%	
46	**Winter Break**	**25 days**	**Thu 12/20/18**	**Wed 1/23/19**			**73%**	
47	Consult w/ sponsors	2 days	Sat 12/22/18	Mon 12/24/18		AV	100%	
48	Improve POC mock-up tombstone	2 days	Fri 12/28/18	Mon 12/31/18		AV,JC	72%	
49	Explore fixturing methods	8 days	Thu 1/3/19	Mon 1/14/19		JC	80%	
50	Create user-friendly interface	8 days	Mon 1/14/19	Wed 1/23/19		JF	60%	

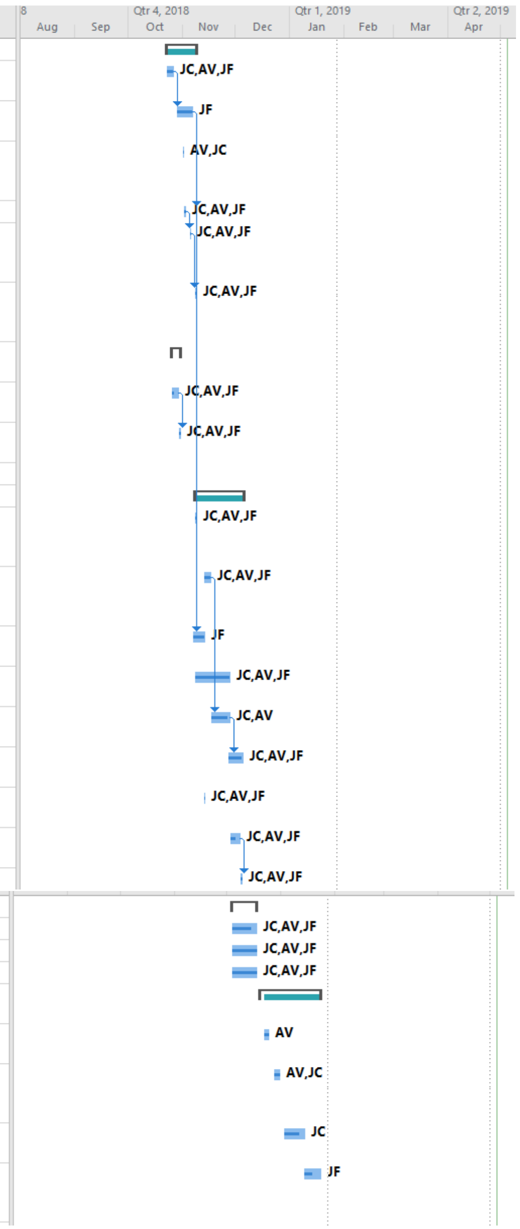


Figure 46: Project Plan detailing the first semester's progress.

Figure 47: Project Plan detailing the second semester's progress.

15.Financial Analysis

Currently, the MAGSEAL process for machining their glands is one at a time. It takes the machinist approximately 18 minutes to create a single gland. Since machining time is fixed at 12 minutes, the objective is to cut down on setup time. If we increase the number of glands on the plate to three glands then the times that can be cut down are the initial set up, replacement, and slider adjusting times.

The number of glands produced in a day is maximized at 36 glands per day. Since the set up time per gland is reduced, the system becomes, in a way, infinitely linkable. This means that each next gland would take the same amount of time to put on the fixture as the previous gland. This also means that a machinist could make 36 glands per day if he were putting one gland on the plate or three glands on the plate. This is an increase of eleven glands per day from the current, theoretical process that MAGSEAL uses now.

If we assume that the machinist is being paid $20/hr for an 8 hour day, $160/day, then the number of glands divided by $160 will be roughly the cost per gland. Since the operating and material costs are assumed to be fixed, only the pay of the machinist will be used in the projected costs. If we assume that it takes roughly 18 minutes to currently produce one gland that means, in an eight hour day, the machinist can produce a total of 26 glands. This means that it costs $6.15 to make gland.

As stated above, the number of glands produced is maximized at 36 per day. This means the cost per gland is reduced to $4.44 per gland. Over the course of a week, based off the projected numbers, the cost of producing glands will decrease by $307.69 with the plate system implemented.

Table 6: The cost of the current manufacturing process vs. the new projected cost of manufacturing.

	Current	Projected
Machine time per gland (min)	12	12
Set-up time per gland (min)	6	1.22
Total time	18	13.22
8 hr Total # of glands	26	36
$/gland	$ 6.15	$ 4.44
$ saved/gland	$0.00	$ 1.71

Regardless of how many glands the machinist can put into the CNC machine at a time, the cost per gland will decrease. A total of $502.01 was spent on the materials to make this device. The cost of machining and designing were not billed therefore will not be taken into account. Since MAGSEAL will save just over $300 a week, the time it takes for this project to be paid for will be just over 1.5 work weeks.

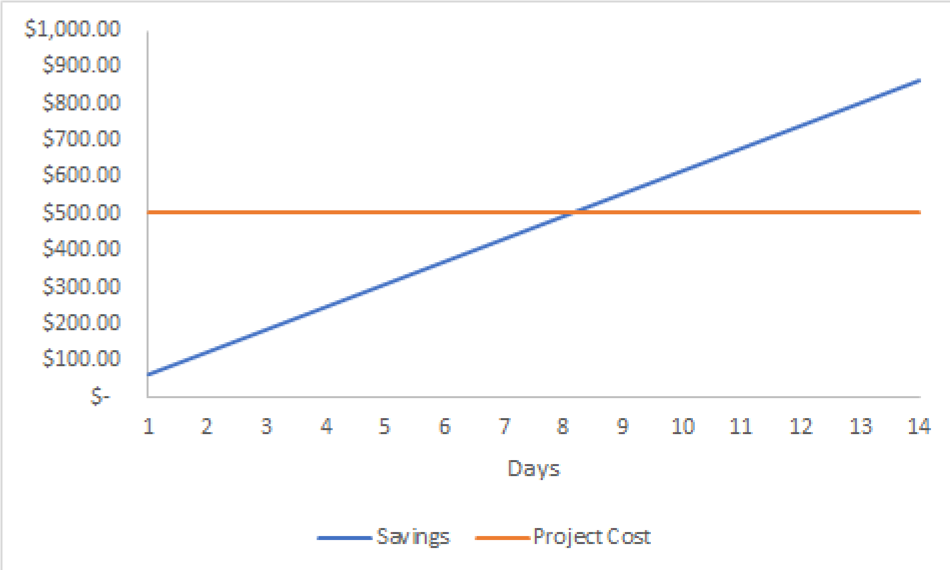


Figure 48: Break Even Timeline

If we assume that cost per gland is a measure of efficiency then as the number of glands in the machine increases so does the efficiency. If we divided the current cost per gland by the projected cost per glands we see an increase in efficiency. Since the time per gland is reduced, therefore more can be made and the cost per gland reduces from $6.15 to $4.44 according to all the cost assumptions that have been made. This cost reduction increases efficiency per gland by 38%. As has been stated, as the cost of each gland decreases the efficiency increases as well as the margin for each gland.

Since this product is only for MAGSEAL an analysis for mass production and market demand are unnecessary.

Human Resource Allocation

The table below represents the number of hours spent by each member of the team on the various tasks set by the team. In some cases it is evident that each team member had their strengths and contributed more or less in certain aspects. This is expected due to the different expertise of each member and is reflected accurately in the hours spent. John spent more time machining because he had more expertise in the machine shop; Jacob spent more time designing and using SolidWorks because he had a better background using the software; and Anthony spent more time making sure that everything was submitted on time, design the poster and brochure, and most administrative work because he is more organized. A total of 480.5 hours were spent working on this project by Team 30 throughout the course of the year.

Table 7: Hours spent on each task by each member of Capstone Team 30.

Task	John	Jacob	Anthony
Machining	25	3	12
Driving	20	16	6
Design	45	50	45
Financial Analysis	2	5	2
Proof of Concept	12	5	12
SolidWorks	3	30	3
Administrative	25	14	32.5
Calculations	4	6	4
Testing	2	2	0
Research	23	26	46
Total hours per member	161	157	162.5
Total hours as a team	480.5		

In order to calculate the theoretical total cost of development, the hours of Team 30 as well as any engineer, consultant, or technician who contributed to this project. The table below shows how each consultant was billed and how the total cost was calculated. The total cost of the project would theoretically cost $14,630 plus the cost of the materials.

Table 8: The total theoretical cost of the Delta Seal gland fixturing device.

	Hours	Hourly Compensation	Total Compensation
Capstone Team 30	480.5	$30.00	$14,415.00
Kevin Smith	3	$30.00	$90.00
Joe Gomez	10	$30.00	$300.00
Dennis Cotnoir	2	$40.00	$80.00
Dave Ferreira	2	$30.00	$60.00
Total (exclude materials)	487	$14,945.00	
Total (with materials)	$15,447.01		

Return on Investment

Return on Investment, by definition, is a performance measure used to evaluate the efficiency of an investment or compare the efficiency of a number of different investments. ROI tries to directly measure the amount of return on a particular investment, relative to the investment's cost. To calculate ROI, the benefit (or return) of an investment is divided by the cost of the investment. The result is expressed as a percentage or a ratio.

The total cost of materials to create this device was $502.01. As previously stated, the savings per week due to the implementation of the device would be $307.69. This means that in 1.6 work weeks, just over 8 work days, MAGSEAL would have saved more than the cost of the materials. This yields a return on investment of 0.613. This is closer to a value of 1 because it pays for itself quite quickly.

However, if the billed hours were paid for the total cost would be $15,447.01. At the rate of savings calculated, it would take 49 weeks before the amount of saving would break even with the total cost. This is reflected by a return on investment value of 0.02.

16. Operation

When implemented, the designed system of an aluminum plate, Mitee-Bite collets, and sliders will be used by a trained machinist to produce MAGSEAL's popular line of gland seals.

Trained machinists have ideally been educated by the company in the machining of the product and are knowledgeable in what it takes to produce a quality product for the customer.

During the production of these gland seals, the machinist has to be able to make decisions in regards to setup, tolerances, and securement of parts and pieces. In this case, THM's machinist Kevin Smith would be the employee who will have the interaction with our product, and he has been informed on the proper operation. To use Capstone Team 30's gland fixturing system, first a gland that needs to be machined must be bought by a consumer. MAGSEAL has developed a program that allows the consumer to build and price their seal over the internet. This system asks the consumer to answer a series of questions about the setup it will be on, measurements, etc., and will produce an engineering drawing of the seal in 3 minutes or less. Once this order is placed by the consumer, a cast stainless steel piece is picked from the stock shelf at THM. This piece is then sized up with an appropriately sized Mitee-Bite collet. The proper collet fits snugly on the inner diameter of the seal and does not move when the center tapered bolt is tightened. Next, the correct collet is placed on the aluminum plate with the gland to be machined over it. The machinist must ensure that the collet is seated in the pocket of the plate with the bottom of said collet making solid, flat contact with the top of the pocket cut into the plate. The three studs in the plate pass through the pre-existing countersunk holes in the collet for use of 10-32 Allen head bolts to keep the collet in the same location while handling fixturing device with the center tapered bolt removed from the assembly. Once the collet is placed on the assembly, the machinist can use the sliders to clock the gland for the proper drilling and tapping action. Not all customers will require the same amount of flush and drain ports, so it is up to the machinist to clock the gland for the proper port drilling. After the proper ports are driller, the gland can be reoriented to machine the faces of the product in order to produce a finished product. The implementation of the expanding ID collets gives the machinist the versatility to be able to machine both sides of the gland without changing the machine setup. Traditionally, the gland would be lever clamped to the table of the CNC machine for this process, which requires resetting of the machine. The reset process in machining is the majority of the time consumed when a machine produces different parts. Each setup has to be carefully measured, zeroed with a dial indicator, and then tested out by the machinist. Because of the unique nature of each gland, there is no cut and dried method of operation that fits the production of every gland. It is up to the machinist to tailor Capstone Team 30's project to the needs of MAGSEAL's customer. In addition to this, our product is only to be used by a trained machinist. A safety guide is not necessary, as a trained machinist is skilled and knowledgeable in how to produce this part while keeping themselves safe. All of the CAD files and assemblies will be transferred to THM and MAGSEAL as a reference in order for them to have a jumping off point if they felt the need to reproduce parts of the assembly in house. The nature of the assembly is extremely simple and with a simple parts breakdown, even someone who is not a trained machinist can assemble the product.

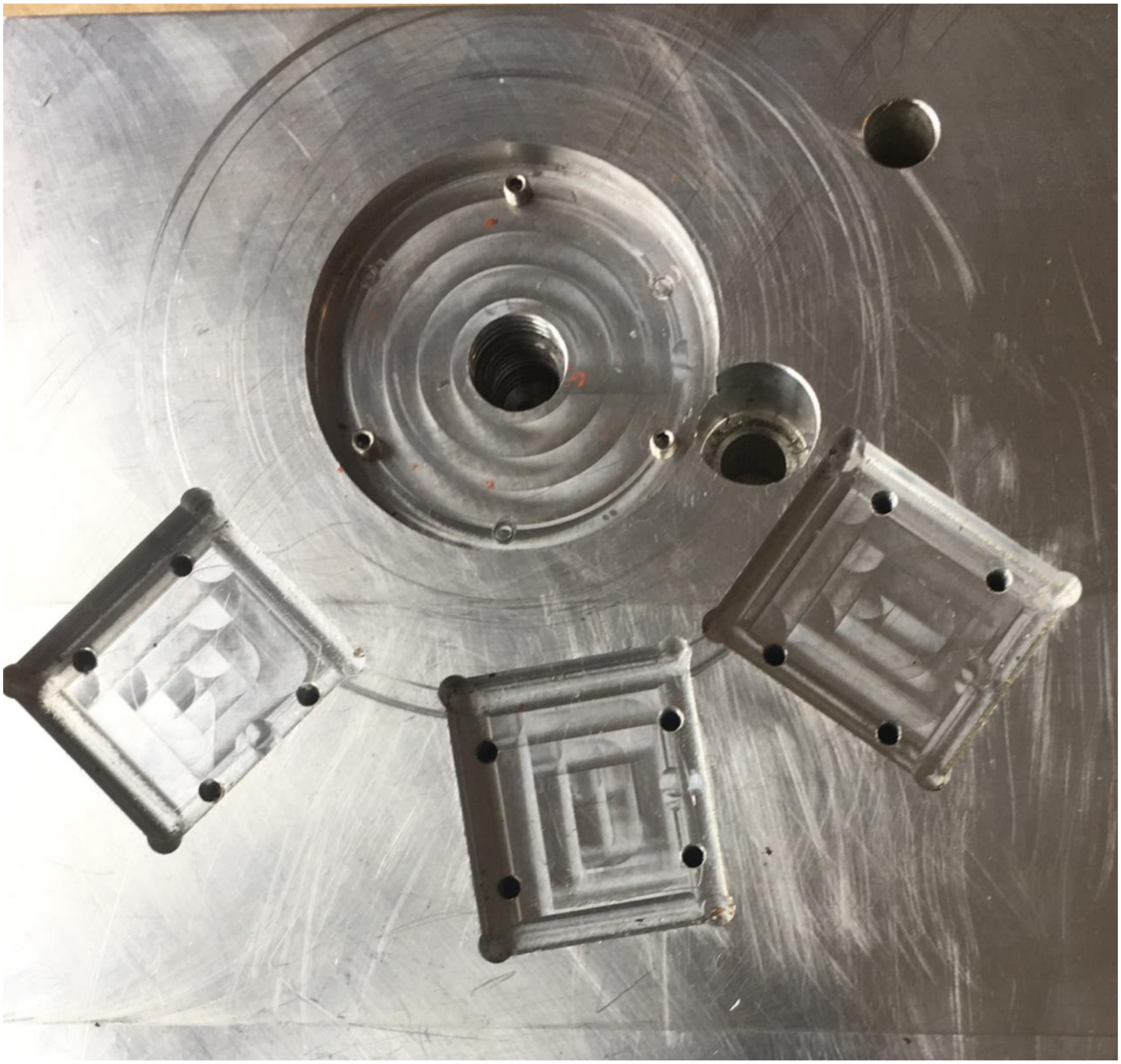


Figure 49: Bare aluminum plate before assembly.

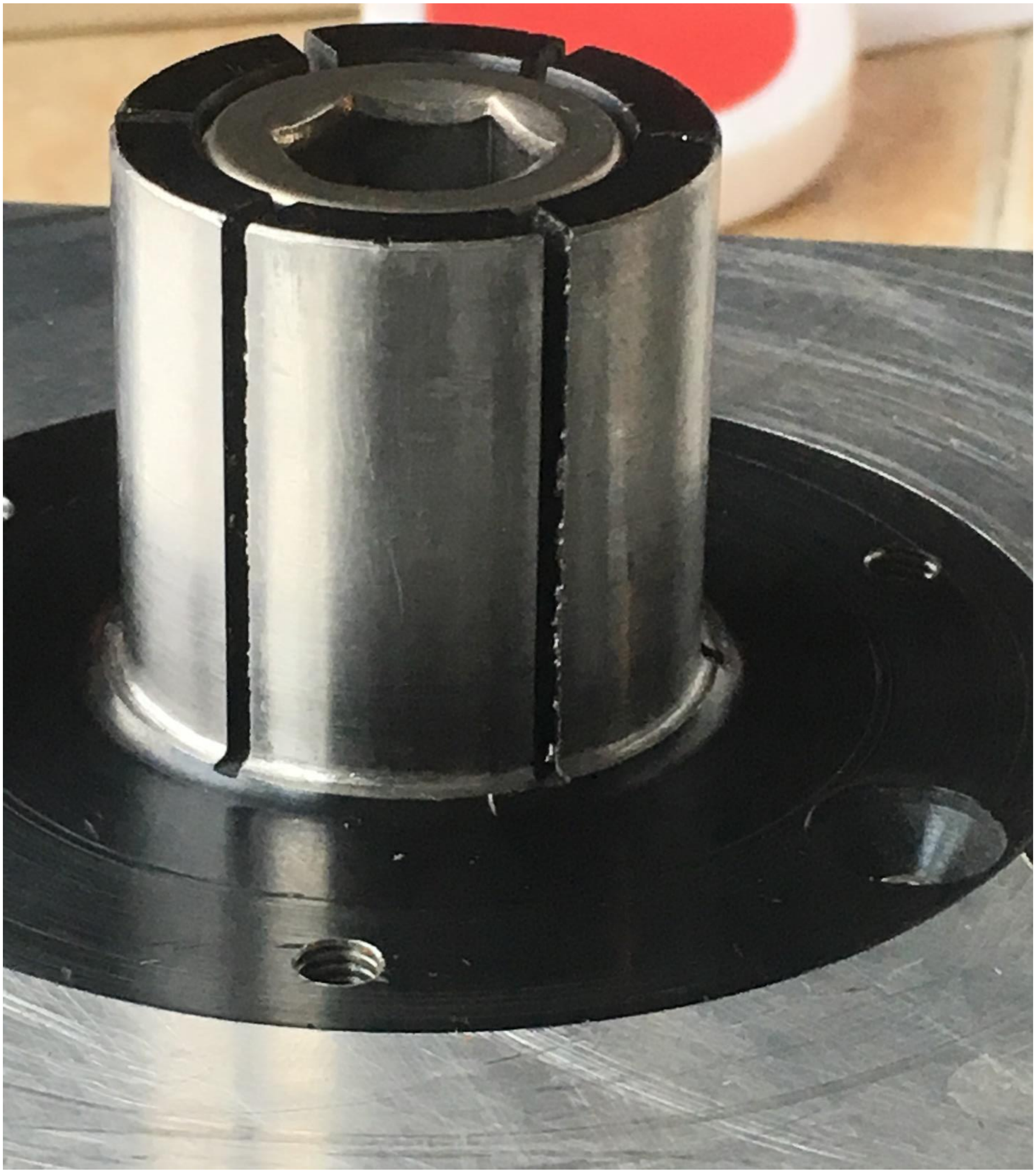


Figure 50: Close up of correct collet to plate fitment. Pictured is the double seal collet.

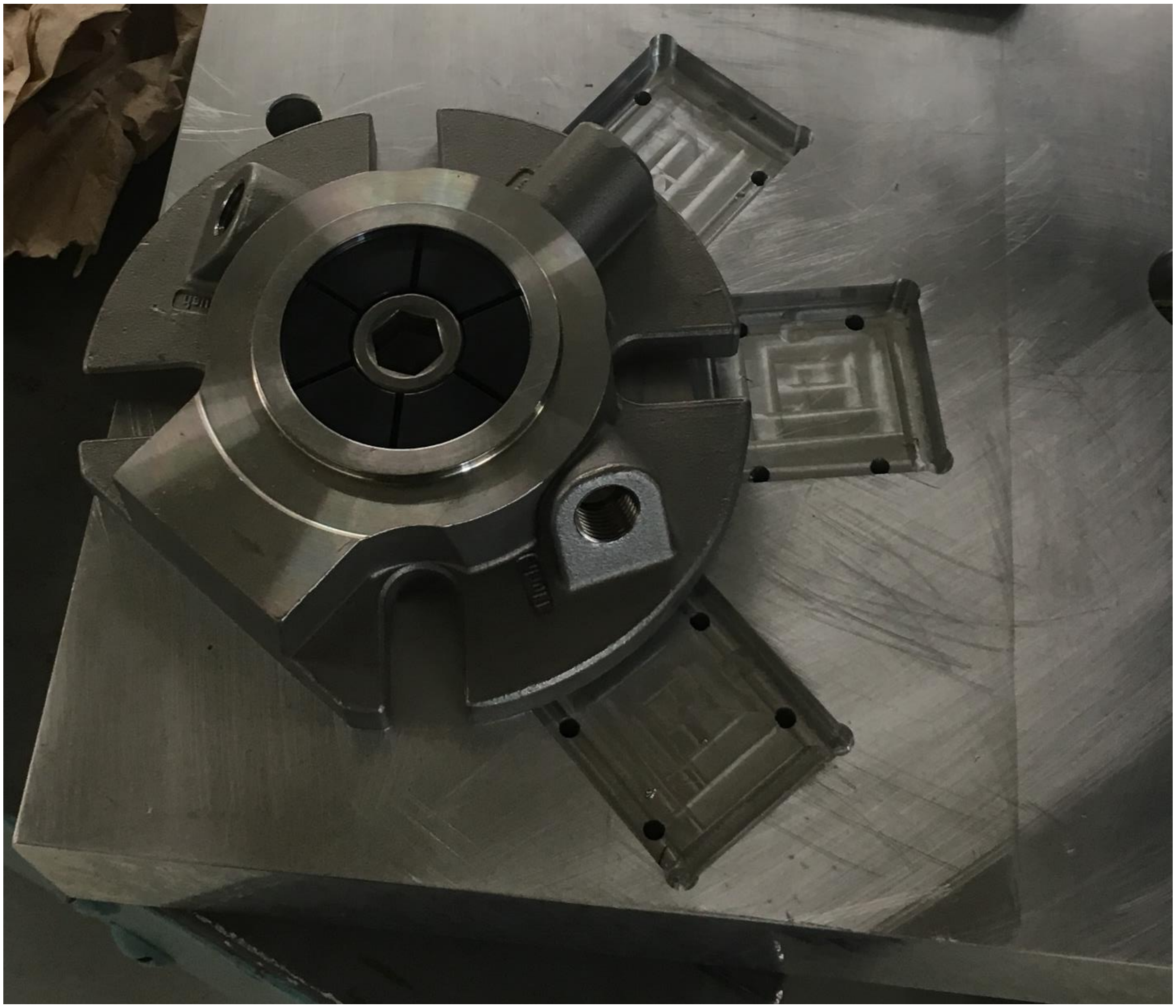


Figure 51: Single seal and collet assembled top view with orientation for flush port drilling and tapping.

17. Maintenance

In order to consistently produce a high quality gland for the customer, the fixturing device will have to be maintained minimally. Most of the maintenance required will be focused on the inspection of the system before and after machining to ensure that no damage has occurred during the process, however there are a few things that should be done as a preventive measure to prolong the service life and allow MAGSEAL to make the most money off of the service of this system. First and foremost is with the collets. In order to ensure easy installation and removal of collets, the machinist must make sure that the machined pockets for the collets in the aluminum plate are free of debris, metal chips/shavings, and machine coolant. A light coat of WD40 goes a long way on the bottom of the collet and in the pocket to make the installation a smooth drop in task as this pocket fits the collets tightly. In addition, below the collet pocket is the 21/32's hole in the plate which was bored to accept a Helicoil for the 5/8-11 tapered bolt. In this case a Helicoil was necessary due to the soft properties of aluminum and the amount of force that the threads would see on a regular basis. With the Helicoil system, the threads are replaceable and modular in the sense that if cross threaded or damaged in any way, the user can spin the threads out of the aluminum plate and insert new ones. The kit provides spare sets of threads with the tap and installation tool. These threads are also stackable by design in case the user needs a longer section of thread engagement. Moving on to the slider portion of the gland fixturing system, the sliders should be inspected periodically for wear. These sliders are strictly for locating and not for providing fixturing support during the machining process. If these sliders are left engaged with the gland while it is being machined, this may cause damage to the locating system by applying excessive amounts of side loads to precision surfaces. When this happens, the fit of the sliders in their sliding tracks will become loose. To test for a bad slider, simply wiggle it left to right before engaging it to the gland. If the slider has any play in it, the clocking measurements will be compromised, and the part will not be drilled in the proper locations. The sliders themselves are low maintenance and will lubricated from machine coolant washing over the travel surfaces during machining. When the assembly begins to yield glands that do not fall within the proper tolerances after machining, and cannot be mended by replacing collets, sliders, or Helicoils, it is time to retire the plate from the duty of machining the gland seals. In the spirit of recycling, THM can repurpose the plate for other uses at the machine shop. To do this, the plate can be re-faced until it is true and can fit its next application. Aluminum plates like these are versatile in nature as they are a blank canvas for machinists and designers to attach parts to or use as a work surface/testing area. When the plate becomes unusable for this, it can be dropped off at a scrap yard. The extruded aluminum plate weighs approximately 55.5 pounds, and according to scrapmonster.com, the middle market value for this is about $0.60 per pound. This gives the plate a scrap value of $33.3 depending on the rate for scrap extruded 6061 aluminum at the time of removal. Since the rest of the project is composed of A2 tool steel and 12l14 steel, these pieces when expired past their service life can be disposed of into a scrap metal bin as they will not bring enough to separate it from the general metal scrap bins at THM.

18. Additional Considerations

Once implemented, Capstone Team 30's project will most likely leave the facility of THM. However, it is still important to analyze the broader aspects of how it can affect the world outside of this facility. Team 30's mission was to provide a way to produce MAGSEAL's gland seals in a more efficient manner, and one must look and see how this product impacts the world for a greater good. The majority of the gland seals that Capstone Team 30 are working with are heading to the food service industry as a mechanical seal that can provide flush and drain ports to remove contamination that may rest within the seal during regular use. While this will not make an impact on the amount of food wasted during the production process, it will cut down on disease from product contamination, and allow manufacturing facilities to pass health and safety tests easier in this category. In addition to the health impacts outside of the facility, there are ways that Capstone Team 30's design will help improve the health, safety, and ergonomics within the facility at THM. When implemented, our design will require less heavy lifting due to the fact that the machinist will be able to keep the 55.5 pound aluminum plate in the machine for more machining processes instead of having the need to switch the plate out for other machining actions on the gland seal. The moving of this plate in and out of the CNC machine is a taxing process for the machinist's back. In addition to reducing the physical strain of the machinist, the Team's design also reduces the amount of time the machinist has in contact with hazardous machine coolant and metal shavings/chips. These chips can become painfully embedded in one's skin, or even worse, make its way into the pocket of the machinist and give them a metal sliver when they reach into it after.

In addition to assisting the health and safety of the machinists at THM, this system of fixturing gland seals will increase the profit of producing these seals. According to THM and detailed in the Team's financial analysis it takes about 12 minutes to machine the seal and 6 minutes to set up the seals for machining. While the Team's design cannot reduce the amount of time it currently takes to machine the gland seals, it can, and will, reduce the time it takes to set up the gland seals to be machined. Our testing indicate that Capstone Team 30 has reduced the setup time for a collet and a gland to 14.75 seconds, which is a large improvement over 6 minutes. Our financial analysis shows that by implementing this setup, THM and MAGSEAL would see a return on investment after 49 weeks on saved time for their machinists with all costs included. Looking at the broader aspects of how this project affects the world outside of THM, the gland seals reduce the amount of food lost due to contamination or possible lawsuits from consumers falling ill from food contamination. Another aspect that these seals will positively impact economically is within MAGSEAL's slogan of "Maximum Critical System Reliability". At varying applications and locations of these seals, any leaks will cause costly downtime, and MAGSEAL's mission is to reduce this downtime in the name of maximum productivity and economic growth with the assistance of science and superior technology.

A clean and reliable source of food has been a motivator for every society since the beginning of time. One of the world's first civilizations, Mesopotamia, took place between the banks of the Tigris and Euphrates rivers in a swath of land known as the Fertile Crescent. This expanse of tenable land became the hotbed of civilization in West Asia due to the land's agriculture in an area surrounded by barren desert. While societies as a whole have moved forward with time, the same issue still remains the same: how to produce good, clean, food. This is where MAGSEAL's gland seal has an impact on society, as well as Capstone Team 30's project. The gland seal's flush and drain ports by design will reduce food contamination from inner sections of the seal, thus reducing the possibility of contamination occurring. This will lead to less food loss due to contamination, and more food on the shelves for consumers. While it may not seem like there is any political impacts on the surface, contamination of is a serious threat to water supplies in our own back yard. Politicians have pledged for the past five years to fix the contamination issues with the Flint, Michigan public water supply and have used this issue as a rallying point to gain support in the area. In comparison, Capstone Team 30's project does not deal with crises of this magnitude, but contamination of consumables can become a political issue when the issue of public health and safety is presented.

Within the profession of engineering, there is a code of ethics that all engineers should abide by to aide their decision making throughout their career. The Engineering Code of Ethics has 6 fundamental cannons, 5 rules of practice, and 9 professional obligations that engineers should consider in their designs and conduct[1]. When designing the gland fixturing system, Capstone Team 30 held these rules paramount with considering design solutions. One of the cannons that is especially important is the first one: "1. Hold paramount the health, safety, and welfare of the public." This cannon applies to the safety and health of the machinist, as our design works to reduce body fatigue and contact with dangerous materials in the workplace while still producing a quality part. In addition to abiding by the Engineering Code of Ethics, Capstone Team 30 also followed the Utilitarianism school of thought. Utilitarianism is based on the belief that "one must do what is best for all that is involved." In order to gain perspective on who falls into the category of being involved with this project, Team 30 looked at the definitive moral audience of this project and all affected by this gland fixturing system being installed and used at THM. For this case, one moral audience was identified as THM machinists, supervisors, and the quality control specialists at MAGSEAL. All of these people are directly involved in the manufacturing of these gland seals, and the difficulty of their job is directly related to the accurate fixturing of these seals. If the system fails accurately locate the piece, then these people have to work harder to create the same part. Another moral audience to consider is within the application of the seals themselves. As stated previously, these seals are involved in keeping food sanitary, so a failure of this seal due to contamination within or intrusion of foreign objects or substances could cause personal injury or death to a consumer. With all these ethical issues considered with Capstone Team 30's project, it is for the greater good of society. Our product is designed to facilitate the creation of cleaner and healthier facilities around the world.

This facilitation begins within the walls of THM and their partnership with MAGSEAL to produce these gland seals. The gland seal fixturing is designed to endure machine processes with minimal maintenance. However, it will expire at some point as a useful piece to the gland seal manufacturing process. Whether new, more efficient technology takes its place, or the gland seal business becomes obsolete, Capstone Team 30's product must be disposed of in a responsible manner. This is not a hard task, as most machine shops have scrap metal bins, however it is in the business's best interest to scrap the aluminum plate separately when it is no longer useful. The plate weighs about 55.5 pounds, and aluminum scrap prices are higher than that of steel. This would require removing of all the clocking devices, collets, Helicoils, and bolts first, and then making a trip to the local scrapyard. With the scrapping of all the materials, the gland fixturing system is melted down, recycled, and then turned into something else depending on where the scrap yard sells their product to.

With the broader aspects considered in this section, Capstone Team 30's project is safe, socially responsible, and if implemented correctly, can help THM and MAGSEAL make more money when this product reaches a demand where mass production is deemed necessary.

19. Conclusions

Capstone Team 30 had been tasked with designing and constructing a device that can effectively clamp and orient Delta Seal gland fixtures for machining. While the problem

[1] NSPE. "Code of Ethics." *Code of Ethics | National Society of Professional Engineers*, www.nspe.org/resources/ethics/code-ethics.

definition changed throughout the course of these two academic semesters, the team was still able to produce a complete SolidWorks file and nearly complete the construction of this concept. The Design Specifications found in Table 9 have been fulfilled through the construction of this fixturing device.

Table 9: Below is a table featuring the Design Specifications of the Delta Seal gland fixturing device that Capstone Team 30 designed.

Parameter	Specification
Materials	• 6061 Aluminum (plate) • 12L14 Steel (collet) • A2 Tool Steel (slide-lock)
Equipment Dimensions	• 12"x24"x2" (plate) • 2.972" flange diameter on collet • Smallest working collet diameter: 1.275" (for small seal) • Largest working collet diameter: 1.937" (for large seal)
Clamping Force	• Maximum of 10,000 lbs
Mounting	• Can load/unload up to 3 seals • Seals can be clocked 3 angles of 45°, 55°, & 100° • Collet diameter for large seal: 1.934" • Collet diameter for small seal: 1.272"

The customer, MAGSEAL, requested a device that could mount more than one Delta Seal gland simultaneously. The original number of glands requested was at least ten, but after some time passed, and invoices were not as high as MAGSEAL had hoped, the number of gland seals required to be on the fixture was reduced to three. The sole reason that the team was reduced to work with three seals simultaneously lies within the 12"24"x2" 6061 Aluminum plate that MAGSEAL provided. Due to these dimensions, no more than three of either gland could be fitted onto the device.

The most difficult portion of this Capstone project was to develop or purchase a mechanism that could clamp and release the Delta Seal glands. After months of conceptualizing designs and searching online for products, the team found the Mitee Bite ID Xpansion collet product line. The correct collet for the customer's needs was found (part no. 31350). The team found that these collets could be turned down on a lathe to fir the smaller and larger sized gland seals, which makes part replacement much easier to do. Because there is a singular clamping part, the collet for the smaller and larger size gland seals have the same size flange diameter of 2.972". This allows for quick interchangeability between the collets depending on what size gland seal is being machined. The material of this collet, 12L14 Steel, is perfect for the customer's application, because it is strong enough to endure any abuse such as accidental drops in the machine shop, but soft enough to not damage the stainless-steel gland seals when tightened. These collets have been tested by the team and do indeed hold the gland seals in place with no difficulty whatsoever.

Another key specification that the customer requested was the proper and precise orientation of the Delta Seal glands, so that drilling at three different angles could occur. The team developed a slide-lock mechanism that allowed for the drilling of different flush ports at angles of 45^o, 55^o, and 100^o. The slide-lock mechanism features a triangular shaped tab with a thumb screw that slides along a track, making it adjustable in order to accommodate multiple sized gland seals. This mechanism is comprised of A2 tool steel, which is an extremely hard variant of steel that is very durable. This design was tested on SolidWorks with both sizes of the gland seals to ensure that it would work. Unfortunately, the team ran out of time and could finish machining the slide-lock mechanism and could not perform any accurate testing with this portion of the fixturing device.

The Delta Seal gland fixturing device that the team produced does have some shortcomings, as with any design project. The team would've liked to have had more time finish the machining of the slide-lock mechanism, so that the entire fixturing device could be tested after being 100% completed. Due to shipping delays and changes requested by MAGSEAL, the team was set back by a few weeks, which is time that could've been very useful towards the end of the spring semester.

MAGSEAL had initially wanted this product to be a one-off design solely for them to use, so potential commercialization of this fixturing device would be essentially nonexistent. The customer was very fond of the design and would like to implement it into their equipment, but the lack of demand for the Delta Seal product line has put the project effectively on-hold for now. This is quite unfortunate, as the team would've liked to have seen their fixturing device in action in order to make any improvements necessary.

The next steps for this project would be to hand over the completely machined hardware to MAGSEAL for it to be finished. As stated before, the team ran out of time to finish the machining of the slide-lock mechanism, so only testing could be done in respect to the collet, which is the clamping aspect of the project. The orienting portion of the project (slide-lock mechanism) should work in theory, but field testing remains to be done.

Overall, the project was a success, because it was 90% complete, and it was done at the expense of around $500.00 of the team's $5000.00 budget. When factoring in labor costs between engineers and machinists, the implementation of this fixturing device would come to a total cost of $1152.01, which would use approximately 23% of the budget provided to the team. Unfortunately, as stated previously, Capstone Team 30 will likely not see their design implemented at this point in time due to the lack of demand of the Delta Seal product line. However, each member has developed a very clear picture of how the entire engineering design process takes place.

20. References

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21. Appendices

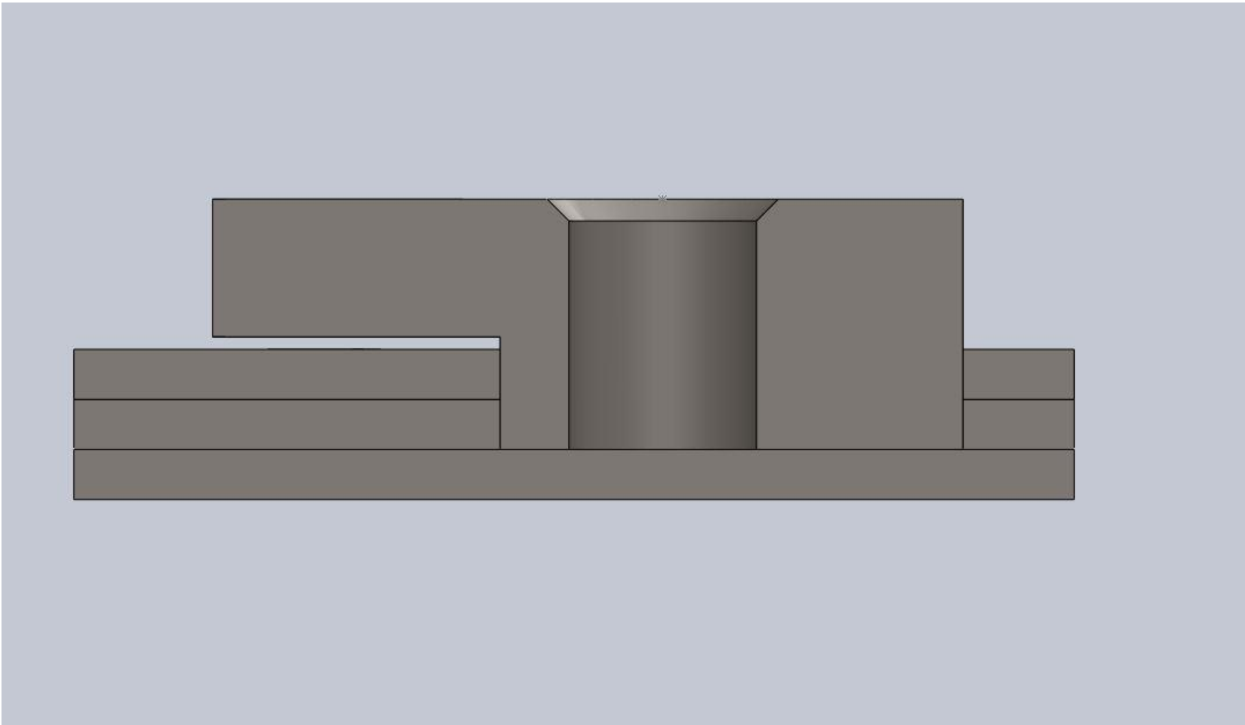

Figure 52: Cross section of the slide-lock mechanism.

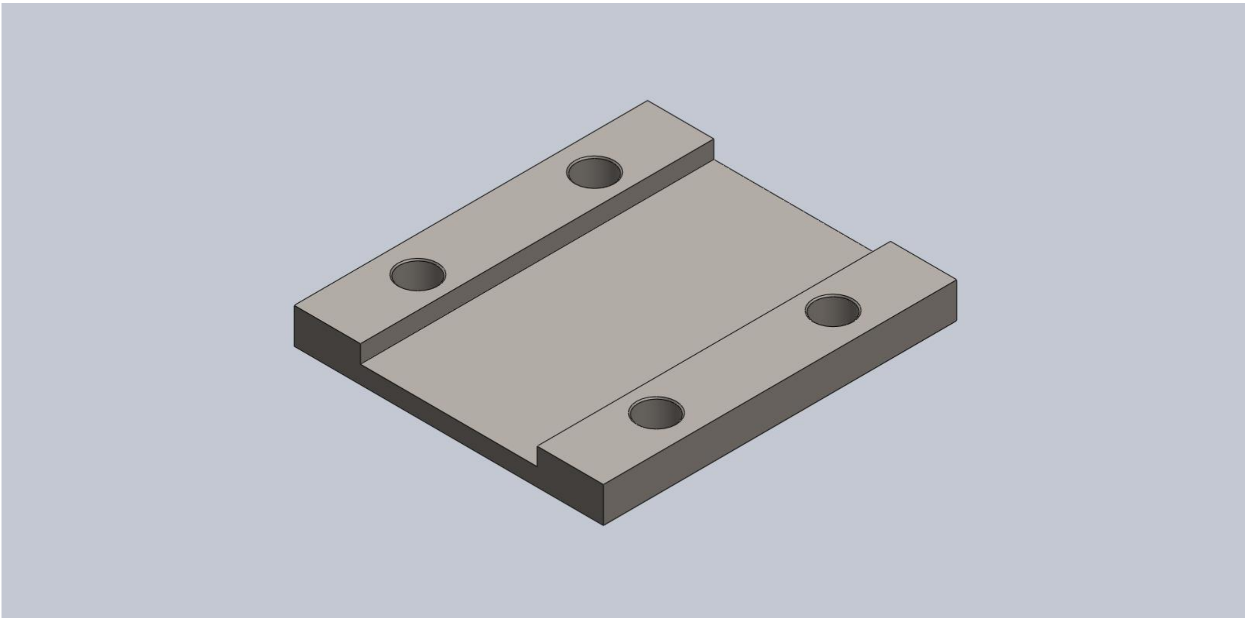

Figure 53: 3-D rendering of the slide-lock base.

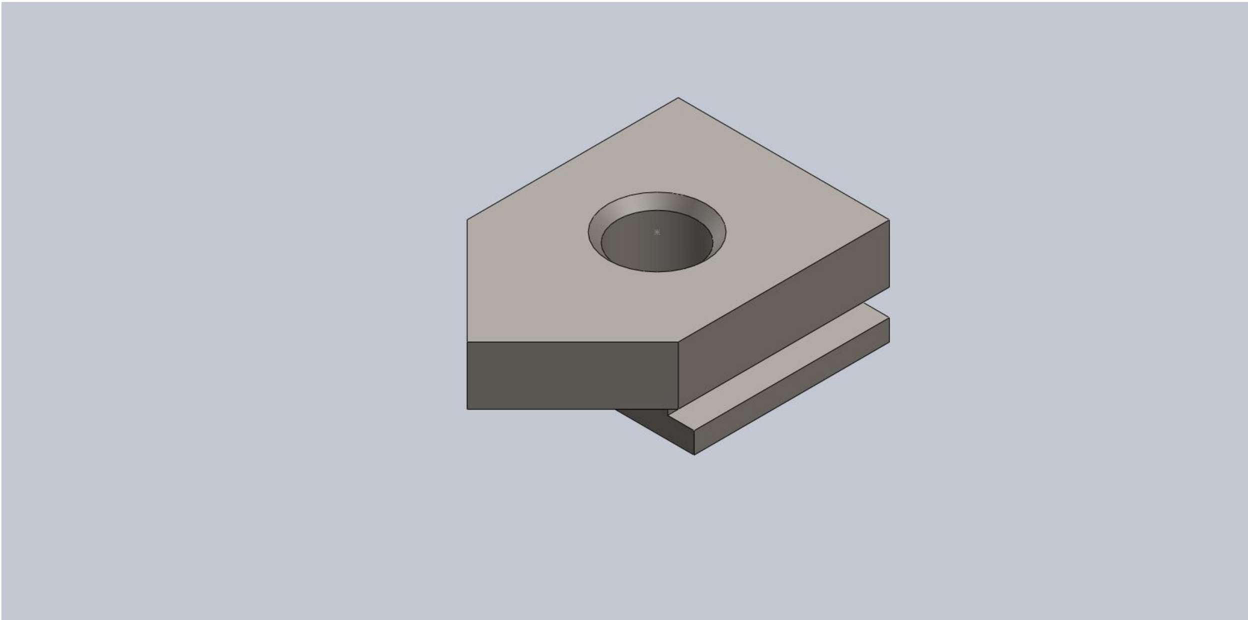

Figure 54: 3-D Rendering of the slide-lock mechanism.

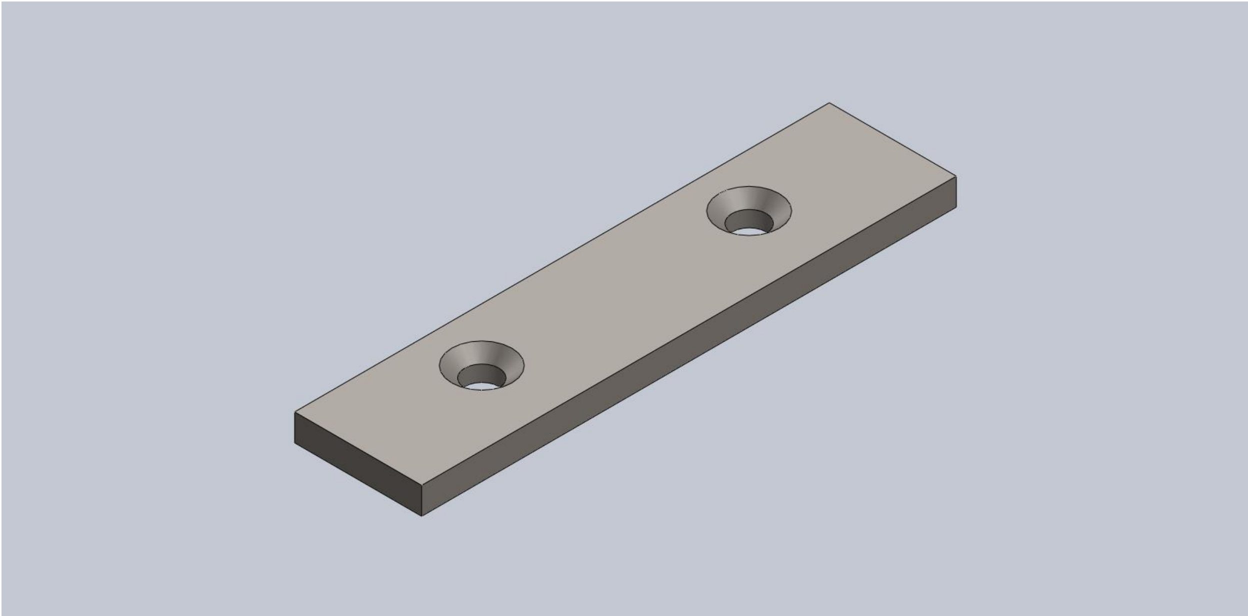

Figure 55: 3-D rendering of the slide-lock channel retainer.

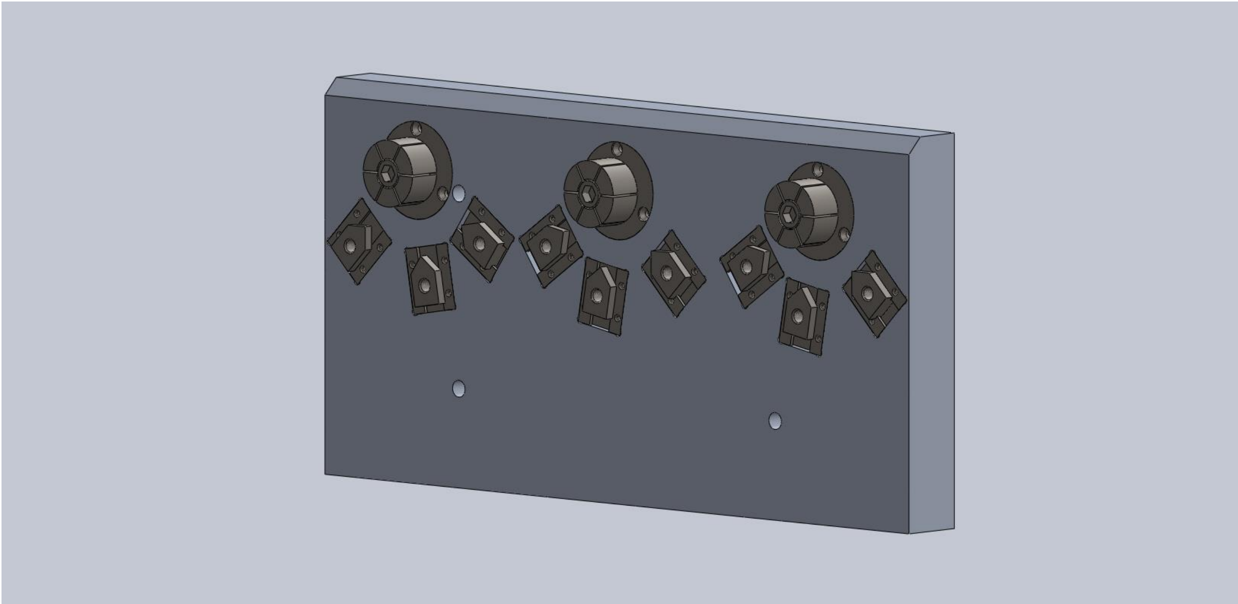

Figure 56: 3-D Rendering of final Delta Seal gland fixturing device.